Module – 5

AIRCRAFT SYSTEMS

Syllabus:

Aircraft Systems:

Mechanical systems and their components; hydraulic and pneumatic systems; oxygen System; environmental Control System; fuel system. Electrical systems, flight deck and cockpit systems; navigation system, communication system.

Aircraft systems (Mechanical) – hydraulic and pneumatic systems and their applications; environment control system; fuel system, oxygen system.

Aircraft systems (Electrical) – flight control system, cockpit instrumentation and displays; communication systems; navigation systems; power generation systems – engine driven alternators, auxiliary power Module, ram air turbine; power conversion, distribution and management.

5.1 Flight Control Systems

The architecture of the flight control system essential for all flight operations has changed significantly over the years. Soon after the first flight, the flight control surfaces were operated through a system of push-pull rods, cables and pulleys. Smaller and less complex aircraft use a simple cable, pulley and push-pull rod system to move the primary flight control surfaces.

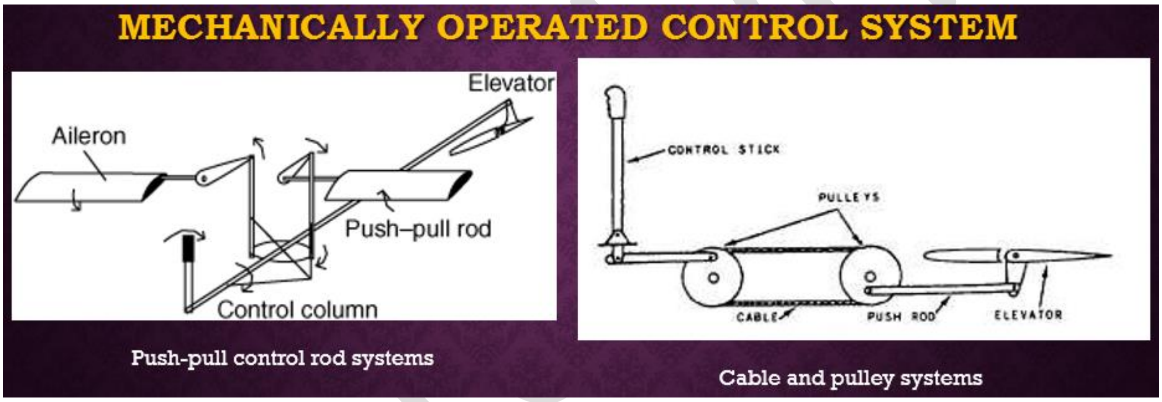
The amount of force required to move the surfaces varies with the speed and angle of attack of the aircraft. Dynamic forces acting on the primary flight control surfaces during all phases of the aircraft operation provide feel feedback to the pilot as to what the aircraft is doing. This dynamic change in control force pressures allows the pilot to develop a feel, the way aircraft is reacting to the control forces.

As aircraft became larger they have correspondingly larger primary flight control surfaces needing higher and higher pilot control forces to move them. The introduction of larger aircraft and increase of the flight envelopes made the pilot effort insufficient in contrast to the aerodynamic hinge moments generated by the control surface deflection. The first solution to this problem was the introduction of aerodynamic balances and tabs. Further increase in the aircraft sizes and flight envelops brought the need of powered systems for control surface movements. The simple direct cable control of flight surfaces is actuated by the hydraulic and servo actuators, which provide the power to move the primary flight control surfaces.

Mechanical Flight Control System

A simple flight control system may be all mechanical or unboosted i.e. operated entirely through mechanical linkages and cables from the control stick to the control surface. It is generally used on small aircraft. The linkage from cabin to control surface can be fully mechanical if the aircraft size and its flight envelop permits. In this case the hinge moment generated by the surface deflection is low, which can be sustained by the pilot. The primary flight control surfaces are moved manually through a series of push-pull rods, cables, bell cranks, sectors, etc.

The two types of mechanical systems are - push-pull rod type and cable-pulley type. In the first case a sequence of rods link the control surface to the cabin input (Fig. 26.2). Bell crank lever is necessary to alter the direction of the force and to obtain the conventional coupling between stick movement and the control surface deflection. Push-pull controls are well known for their ease of movement.



Push-pull rods eliminate the problem of varying cable tensions. A single push-pull rod can transfer either tension or compression loads whereas a cable-pulley system can only handle tension loads. Although individual cables are lighter than push-pull rods, the cable-pulley systems, particularly in high wing aircraft, do require fabrication and installation of large number of pulleys, brackets and guards. As a consequence, the cable installation tends to become heavier and more complex. Additionally, the numerous pulleys and higher cable tensions generally result in a control system that may generate a need for heavy control pressures because of friction.

In the second type of mechanical arrangement of cable-pulley system, cables are used in place of the rods. In this case pulleys are used to alter the direction of the lines, equipped with idlers to reduce any slack due to structure elasticity, cable strands relaxation or thermal expansion. A typical cable-pulley system is shown in Fig. 26.3.

In the cable-pulley system, a quadrant is usually employed at the base of the control column to impart force and motion to the cable system. A torque tube is attached to the control surface, which changes linear motion of the cable into rotary motion to deflect the control surface. In case of large aircraft, often the cable-pulley solution is preferred over the push-pull rod system, because it is more flexible and allows reaching more remote areas of the aircraft. For pressurised aircraft, the control cables pass from pressurised section to unpressurised section through air pressure seals.

Hydraulically Operated Flight Control System

Hydraulically operated flight control system or powered flight controls are used on high speed and large aircraft. Aircraft travelling at high speeds impose high loads on the primary control surfaces. As such, it is impossible for a pilot to control the aircraft without power assisted or power operated flight control systems. Both the systems in basic form are similar in that a hydraulically operated servo control unit, consisting of control valve and an actuating jack, is connected to the control column and the control surfaces (Fig. 26.4). The only difference is the method of connecting actuating jacks to the control surfaces.

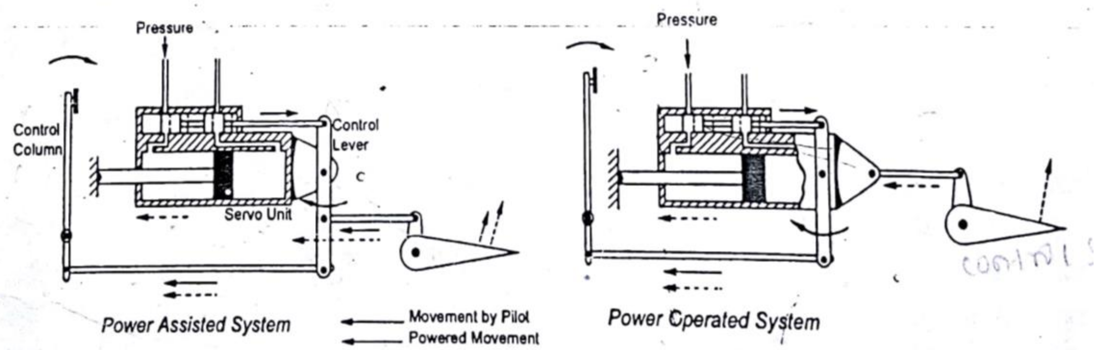
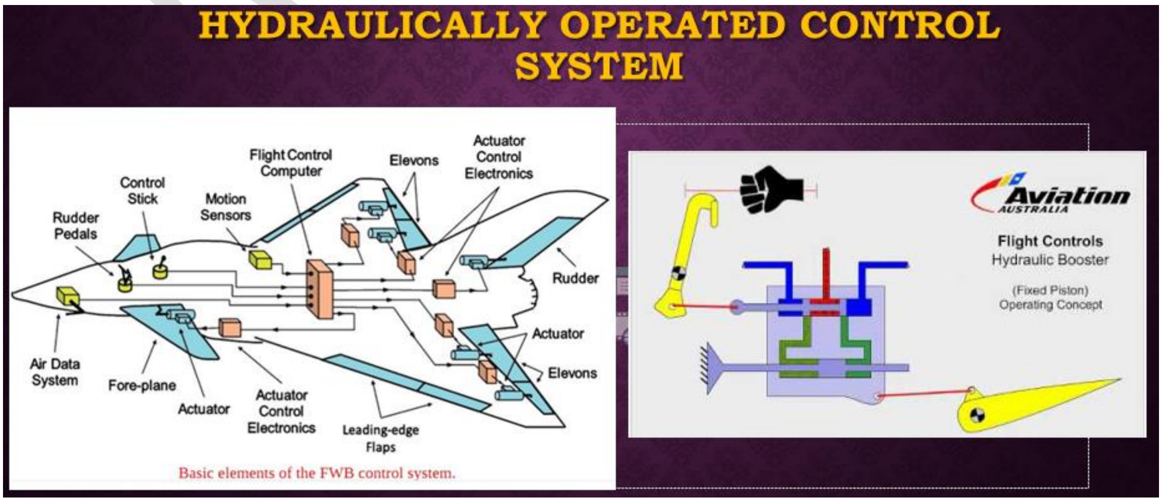


Fig. 26.4

In the power assisted system, the control column is connected to the control surface through a control lever. In the power operated system, the control column is connected to the control lever only and the servo unit is directly connected to the control surface. The force necessary to operate the control surface is supplied by the hydraulic pressure.



Since the force necessary to operate the control surface is supplied by the hydraulic pressure in the power operated system, no forces are transmitted back to the cockpit. As such, the flight crew has no feel of the aerodynamic loads acting on the control surfaces. For such systems, it is, therefore, necessary to incorporate an artificial feel device at a point between the cockpit controls and the servo unit control lever.

The basic principle of the hydraulic control is simple. However, the system must control the surface in a proportional way, i.e. the surface response (deflection) should be a function of the pilot's demand (stick deflection, for instance). This is achieved by using hydraulic servo-mechanisms, where the components are linked in such a way to introduce an actuator stroke proportional to the pilot's demand.

5.2 Hydraulic system

- Hydraulic system: Transmits the power from one point to another through the incompressible fluids like oil.
- A hydraulic system uses a fluid under pressure to drive machinery or move mechanical components.
- Virtually all aircraft make use of some hydraulically powered components.
- In light, general aviation aircraft, this use might be limited to providing pressure to activate the wheel brakes.
- In larger and more complex aero planes, the use of hydraulically powered components is much more common.
- Depending upon the aircraft concerned, a single hydraulic system, or two or more hydraulic systems working together, might be used to power any or all.

Advantage of hydraulic system:

- Light weight and easy to maintain
- Efficiency almost 100% with negligible losses due to friction
- We can develop practically unlimited force
- Easily transfer the force in curved path also

Disadvantage of hydraulic system:

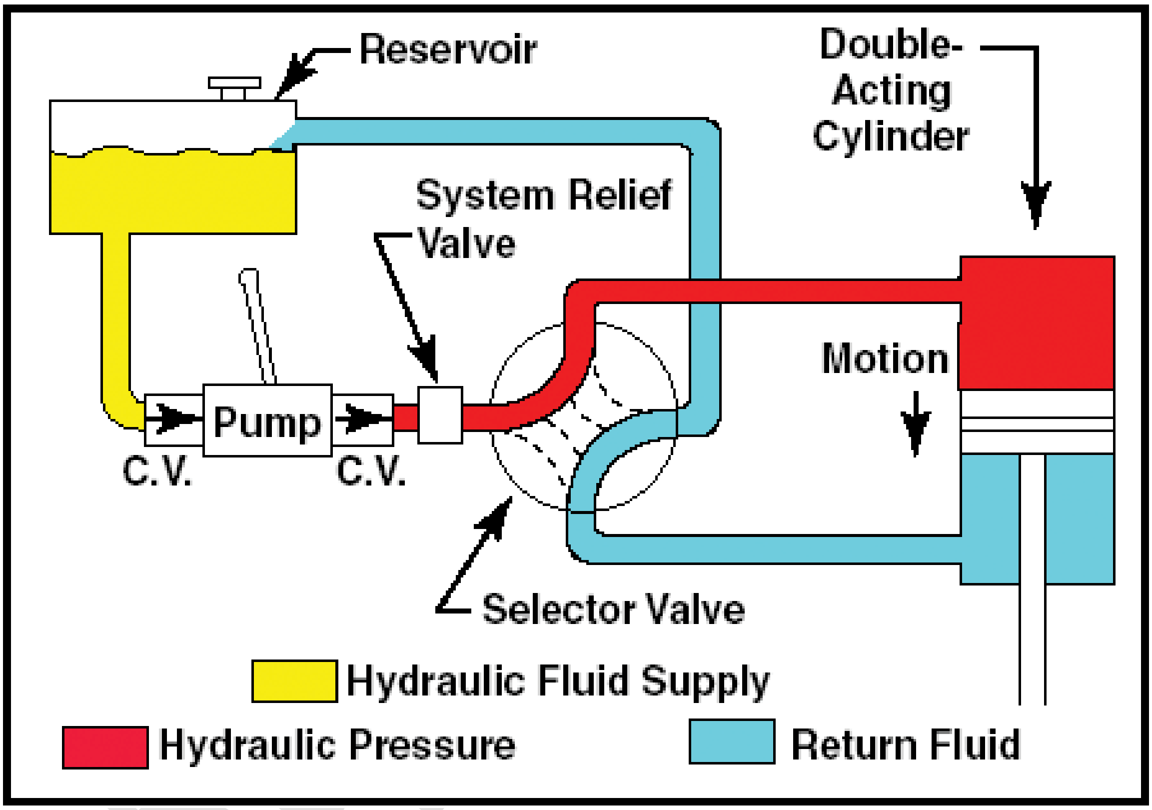
- Possibility of leakage
- Contamination by foreign matter in the system can cause malfunction of any unit

Parts Controlled by Hydraulic System:

- Wheel brakes
- Nose wheel steering

- Landing gear retraction/extension
- Flaps and slats
- Thrust reversers
- Spoilers/speed brakes
- Flight control surfaces
- Cargo doors/loading ramps
- Windshield wipers
- Propeller pitch control

Basic Components:



A hydraulic system consists of the hydraulic fluid plus three major mechanical components. Those components are:

- The "pressure generator" or hydraulic pump
- The hydraulically powered "motor" which powers the component concerned
- The system "plumbing" which contains and channels the fluid throughout the aircraft as required.

Hydraulic Fluid:

- Fluid is the medium via which a hydraulic system transmits its energy and, theoretically, practically any fluid could be utilized.

- The operating pressure (3000 to 5000 psi) that most aircraft hydraulic systems generate.
- High Flash Point.
- In the event of a hydraulic leak, fluid ignition should not occur at the normal operating temperatures of the surrounding components.
- Special hydraulic fluids with fire resistant properties have been developed for aviation use. These fluids are phosphate esters and, unlike mineral oil based hydraulic fluids,
- Adequate Viscosity
- Lubricant Properties.
- Thermal Capacity/Conductivity

Hydraulic Pumps:

- Gear Pumps: Gear pumps use meshing gears to pump fluid. Gear pumps are fixed displacement type pumps as they move a specific amount of fluid per rotation. Gear pumps may be used on low pressure systems (under 1500 psi) but are generally not suitable for high pressure applications
- Fixed Displacement Piston Pumps: Piston pumps utilize a piston moving in a cylinder to pressurize a fluid. A fixed displacement pump moves a specific amount of fluid with each stroke.
- Variable Displacement Piston Pumps: This is the most common type of pump on large aircraft. The variable displacement design allows the pump to compensate for changes in the system demand by increasing or decreasing the fluid output. This allows near constant system pressure to be maintained.

Hydraulic system for aircraft:

A typical hydraulic system for a large aircraft (Fig. 27.10) consists of a main hydraulic system and auxiliary hydraulic system. Both the systems are independent of each other.

The main hydraulic systems are designated as System A and System B. System A has most of its components on the left side of the aircraft and system B on the right side. Hydraulic systems A and B operate independently to supply hydraulic power to the aircraft systems. Both systems operate at about 3000 psi ($207x10^3$ mb) normal pressure and are almost the same. Each system is pressurised by the pneumatic system. Hydraulic system A and B supply pressurised fluid to the following systems:

- Thrust reverser
- Power transfer unit (PTU) pump and motor
- Landing gear extension and retraction
- Nose wheel steering
- Normal and alternate brake
- Ailerons
- Autopilots
- Elevators
- Elevator feel
- Flight and ground spoilers
- Rudder
- Trailing edge flaps
- Leading edge flaps and slats

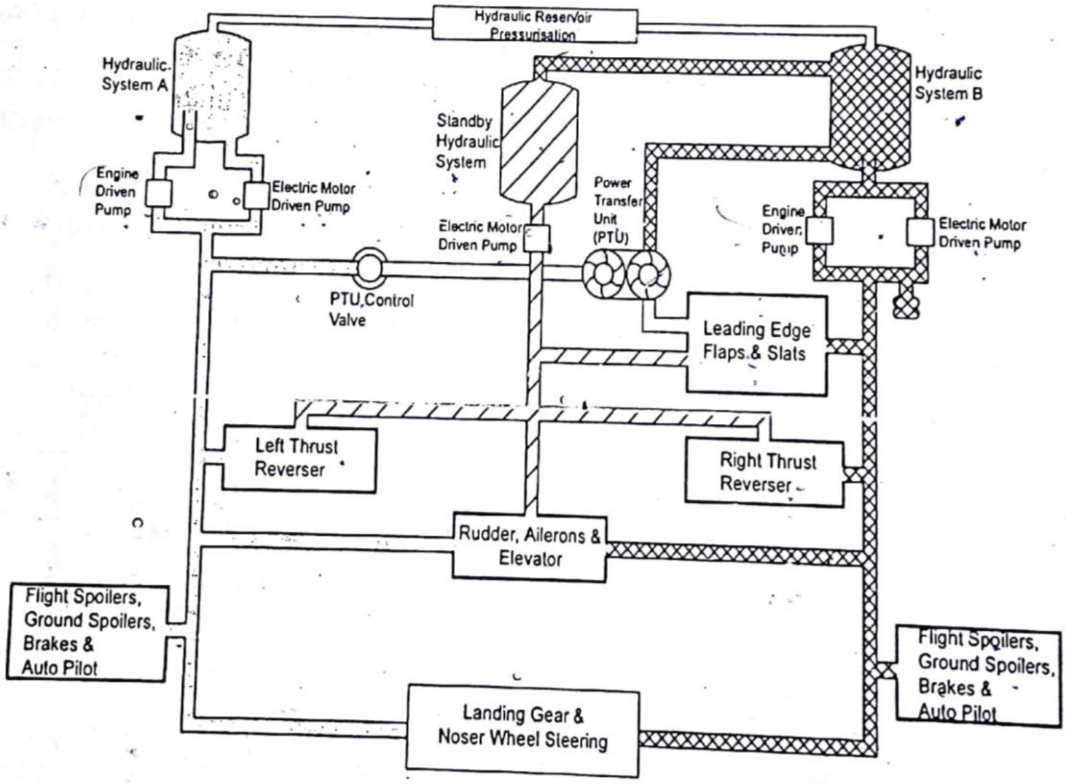


Fig. 27.10

The auxiliary hydraulic system is the standby hydraulic system. It is an alternative or backup pressure source to hydraulic systems A and B and operates automatically or manually. It is a demand system that supplies reserve hydraulic power to actuating units like leading edge flaps and slats, thrust reversers, etc.

The pressurised reservoirs supply a constant flow of fluid to the hydraulic pumps. The reservoirs also get return fluid from the aircraft systems that use hydraulic power. The pneumatic system pressurises the hydraulic system reservoirs to about 45-50 psi (3.1×10^3-3.4×10^3 mb).

The system uses engine driven pumps and electric motor driven pumps to supply hydraulic pressure. The engine driven pump is an axial-piston, variable displacement and pressure compensated hydraulic pump. Both the engine driven pump and the electric motor driven pump supply hydraulic pressure for hydraulic systems A and B.

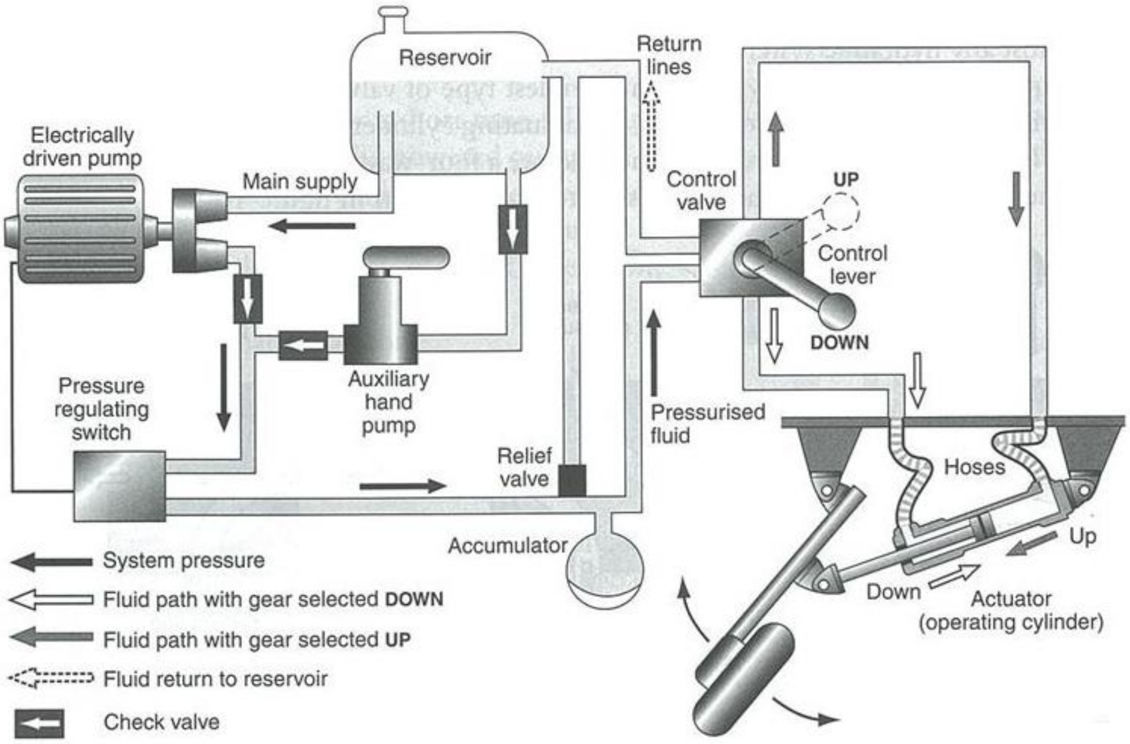


Fig: Hydraulic system for light aircraft

5.3 Pneumatic System

Aircraft pneumatic systems are primarily used as emergency sources of pressure for hydraulically operated sub-systems. Since air is the main source for transmitting power in a pneumatic system, there is no requirement of return system. Some aircraft use low pressure whereas some use high pressure pneumatic system. The type of system required to be used is determined by the air pressure requirements. The pneumatic system supplies air for the following:

- Air conditioning and Pressurisation,
- Engine starting,
- Anti-icing/de-icing,
- Hydraulic reservoir pressurisation,
- Emergency lowering of landing gear and braking,
- Nose wheel steering,
- Passenger doors, etc.

LOW PRESSURE SYSTEM

On large turbine engined aircraft, the pneumatic system is primarily used for engine starting, anti-icing/de-icing, air conditioning and pressurisation. Generally, the regulated pressure in the system is of the order of 45 to 50 psi (3.1×10^3 to 3.5×10^3 mb). The sources of pneumatic power (Fig. 28.1) are as follows:

- Engine bleed air,
- Auxiliary Power Unit (APU), and
- Ground source.

Engine Bleed Air

In general, there is one bleed air system for each engine. The engine bleed air system controls bleed air temperature and pressure. Engine bleed air is tapped from the appropriate stage of a high pressure compressor. A bleed air regulator and pressure regulating shut-off valve control the flow of bleed air to the pneumatic manifold. A pre-cooler system controls the engine bleed air temperature.

APU Bleed Air

The APU supplies bleed air to the pneumatic manifold. For aircraft having an APU, a check valve is installed, which protects the APU from engine bleed air flow.

The pneumatic manifold system gets bleed air from the engines, APU, or ground source. A bleed air isolation valve divides the pneumatic manifold into left and right sides. The normal position of this valve is closed and as a result, a single duct failure cannot cause a loss of pressure to the whole pneumatic manifold.

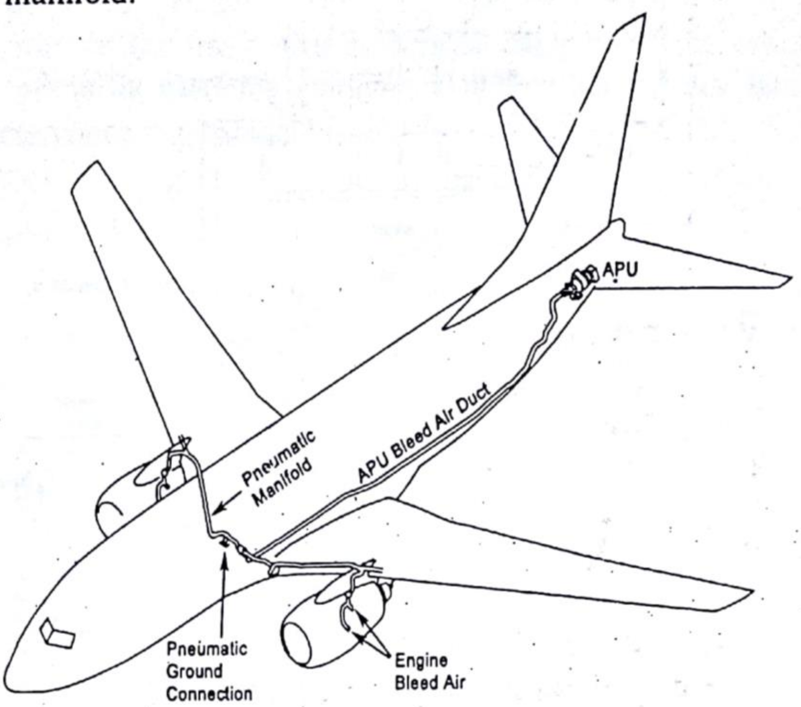


Fig. 28.1

The unregulated air from the engine compressor passes through the pressure regulator, which reduces the pressure to a constant value. A relief valve prevents damage to the system in the event of a pressure regulator failure. The bleed air regulator operates the pressure regulating shut-off valve. This valve controls the flow of bleed air from the engine to the pneumatic manifold. The bleed air regulator has overpressure switch to prevent overpressure conditions. The functional description of low pressure pneumatic system is shown in Fig. 28.2.

A pre-cooler system, which is generally automatic, cools the engine bleed air. It is a cross flow type heat exchanger. It uses engine fan air to cool the engine bleed air. The pre-cooler system controls engine bleed air temperature to 199°-227°C (390°-440°F). As the engine bleed air moves through the pre-cooler, the bleed air gives up heat to the walls of the pre-cooler. The walls are made of plates and fins. Engine fan air that goes through the pre-cooler on the other side of the walls removes the heat and carries it away. Heat transfer goes from the bleed air to the pre-cooler walls and to the fan air. The fan air then flows over the engine case and overboard through the vent lines. A generalised pneumatic distribution system is shown in Fig. 28.3.

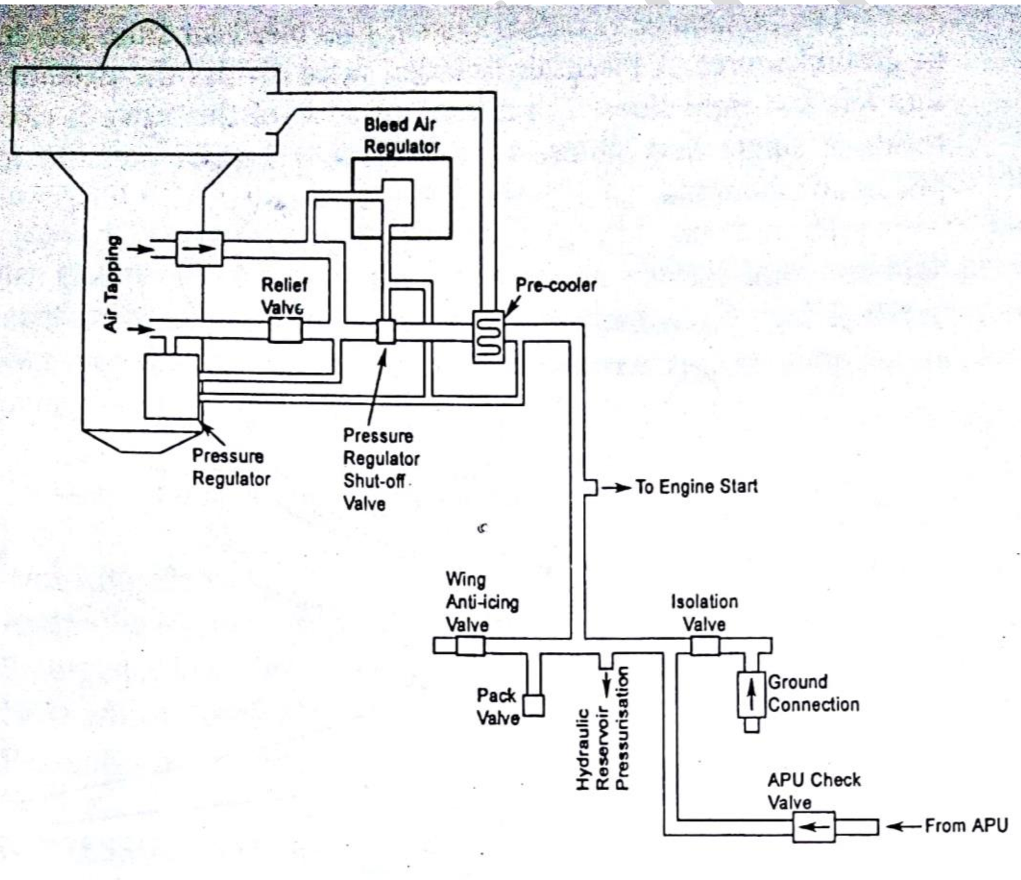


Fig. 28.2

HIGH PRESSURE SYSTEM

The high pressure pneumatic system usually consists of one or more high pressure air cylinders, pressure gauges and pressure warning lights. Such a system is used for operation of landing gear, wheel brakes, flaps, doors, etc.

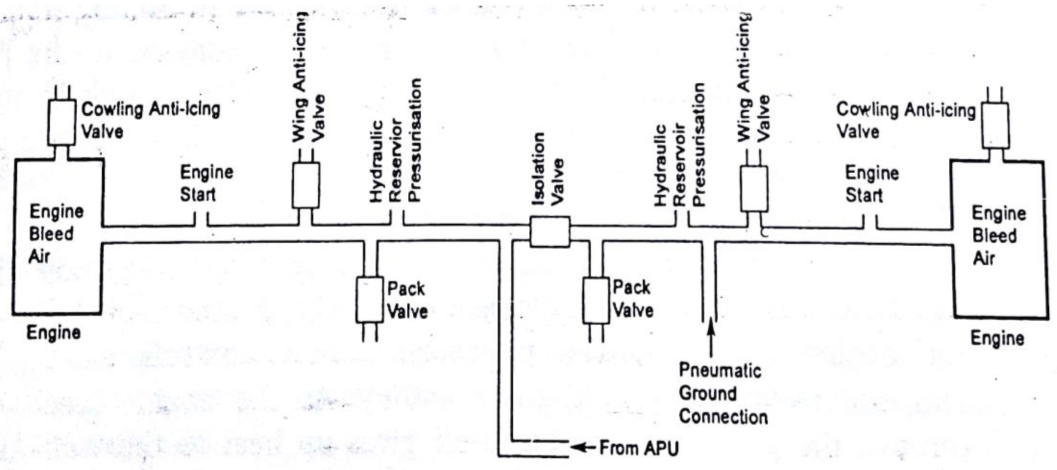


Fig. 28.3

For high pressure system, the air is stored in metallic cylinders at pressure ranging from 1000-3000 psi (69×10^3-207×10^3 mb). The cylinder has two valves viz. charging valve and the control valve. The charging valve is connected to the ground source for filling air. The control valve acts as a shut-off valve, which keeps the air trapped in the cylinder until the system is operated (Fig. 28.4). This type of pneumatic power source does not replenish itself during flight and the compressed air supply is sufficient only for a certain number of operations. The storage cylinder must be filled with compressed air or nitrogen prior to the flight. Due to limited capacity of the cylinder, such systems are primarily used for emergency brakes, emergency landing gear extension, emergency flap extension, etc.

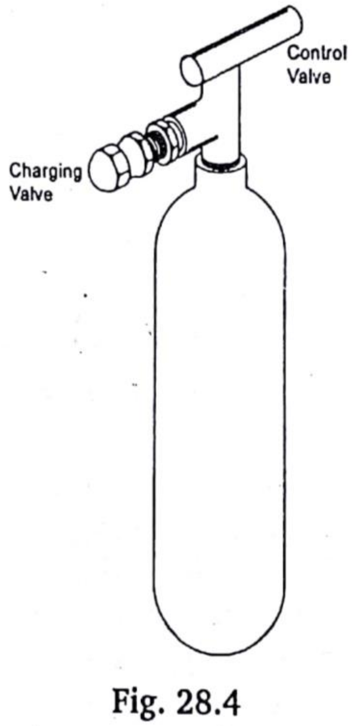


Fig. 28.4

Some aircraft use air compressor to recharge the air-cylinder, which ensures adequate supply of compressed air during the flight. The air compressor used in most aircraft is driven by a hydraulic motor. Aircraft that have an air compressor use the compressed air for both normal and emergency system operations.

A typical high pressure pneumatic system is shown in Fig. 28.5. The compressor is driven by the accessory gearbox of the engine. The discharge air from the compressor is directed to the unloading valve. The unloading valve maintains the system pressure. When the pressure rises beyond 3300 psi ($228x10^3$ mb), it unloads the compressor by dumping its output overboard. On the other hand when the system pressure drops below 2900 psi ($200x10^3$ mb), the compressor is loaded and its output is directed back into the system.

A shuttle valve installed between the compressor and the main system makes it possible to charge the system from the ground source. When the engine is not running and air pressure is supplied from the external source, the shuttle slides over and isolates the compressor.

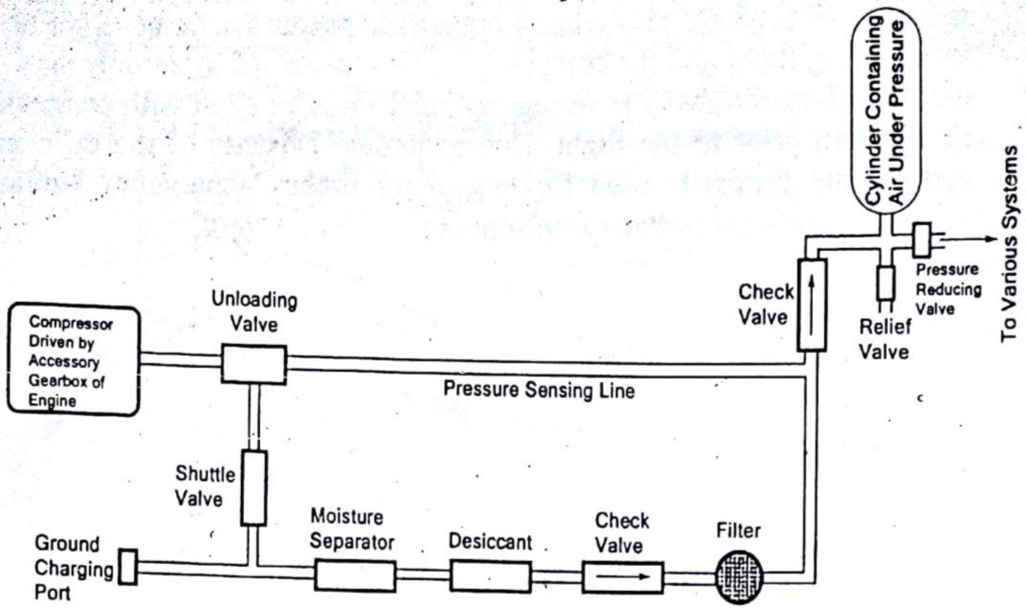


Fig. 28.5

A moisture separator collects the moisture from the air and holds it until the system is shut down. When the inlet pressure to the separator drops down below 450 psi ($31x10^3$ mb), a drain valve opens and the accumulated moisture is discharged out. Air from the moisture separator with more than 95% moisture passes through a desiccant (or a chemical dryer) where traces of the moisture are removed. The air then passes through a sintered metallic filter of about 10 microns. This ensures that air going to main system is free from moisture and contaminants. The storage air cylinder is used for both normal and emergency operations. Most of the components in the pneumatic system operate at a ...

system operate at a pressure of about 1000 psi (69×10^3 mb). As such a pressure reducing valve is installed, which reduces air pressure for normal operation of landing gear, passenger doors, nose wheel steering, etc. In addition to reducing the pressure, it also serves the function of relief valve.

PNEUMATIC SYSTEM COMPONENTS

Air Filter

An air filter is used in the system lines to remove any foreign matter that may enter the system. Air filters have a removable element and a built-in relief valve. The relief valve is designed to open and bypass the air supply around the filter element in the event of element getting clogged. Some air filters have micronic type paper element, which must be replaced periodically. Others have the screen-mesh type, which can be re-used after periodic cleaning. A typical micronic type and screen mesh type filter is shown in Fig. 28.6.

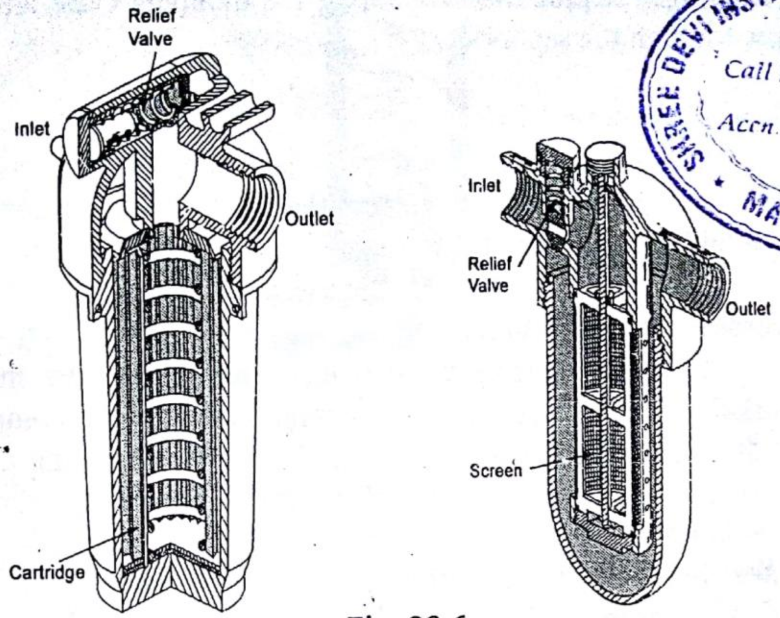
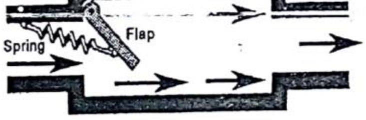


Fig. 28.6

Check Valve

Check valves used in the pneumatic system are of flap type (Fig. 28.7). They are also one direction flow control valves. Air enters from one port and compresses the spring, which forces the check valve to open. This allows the air to flow out of the other port. However, if the air enters from the out port, the air pressure will close the valve thereby preventing the air flow from inlet port.



Desiccant/Chemical Dryer

The purpose of a chemical dryer is to absorb any moisture that may collect in the lines and other parts of the system. Each drier contains a replaceable cartridge, which is blue in colour. If change in colour is observed, the cartridge is to be considered contaminated with moisture and should be replaced.

Moisture Separator

The purpose of moisture separator is to remove any moisture caused by the compressor. A complete moisture separator consists of a reservoir, a pressure switch, a drain valve and a check valve. The check valve protects the system against pressure loss during the dumping cycle and prevents reverse flow through the separator.

Bleed Air Isolation Valve

The bleed air isolation valve separates the pneumatic manifold into right and left sides and connects the right and left sides of the pneumatic manifold for cross bleed operation.

Pressure Reducing Valve

Pressure reducing valve reduces the air pressure in the cylinder to a workable pressure required for operation of certain components. A typical pressure reducing valve is shown in Fig. 28.8. When the pressure in the low pressure system is below the valve setting, the spring extends and moves the inlet valve plunger. This movement causes air from high pressure system to enter the valve. As the pressure in the low pressure system increases, the bellow compresses the spring and returns the inlet valve plunger to the close position.

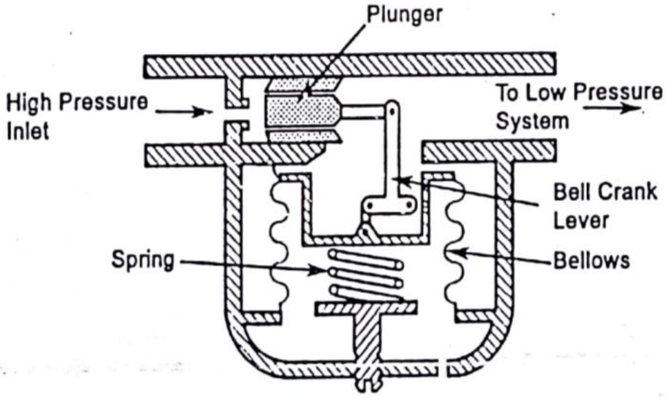


Fig. 28.8

Relief Valve

Relief valve is used to protect the system from over pressurisation. It acts as a pressure limiting unit and prevents excessive pressure from bursting the pneumatic lines. Relief valves are generally adjusted to open and close at pressures slightly above normal system operating pressure. A typical relief valve is shown in Fig. 28.9.

At normal pressure, the valve is closed under the spring action. However, if the pressure becomes too high, it forces the disk to move up and opens the relief valve. The excess air flows through the valve before it is released to the atmosphere. The valve remains open until the pressure drops to normal value. At this stage, the disk returns to its original position.

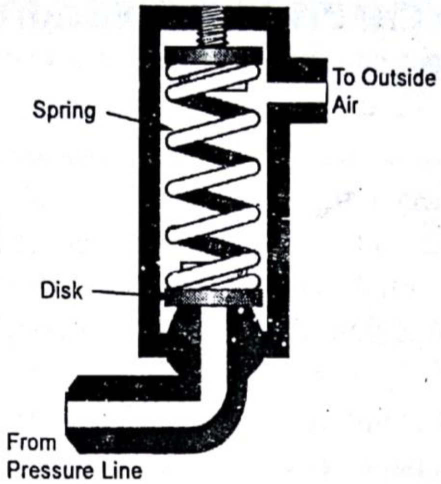


Fig. 28.9

Shuttle Valve

Shuttle valve allows the pneumatic system to operate from the ground source. When the pressure from the external source is higher than that of the compressor, the shuttle slides over and isolates the compressor. Shuttle valve is also used to provide an emergency pneumatic backup for hydraulically operated landing gears. A typical shuttle valve is shown in Fig. 28.10.

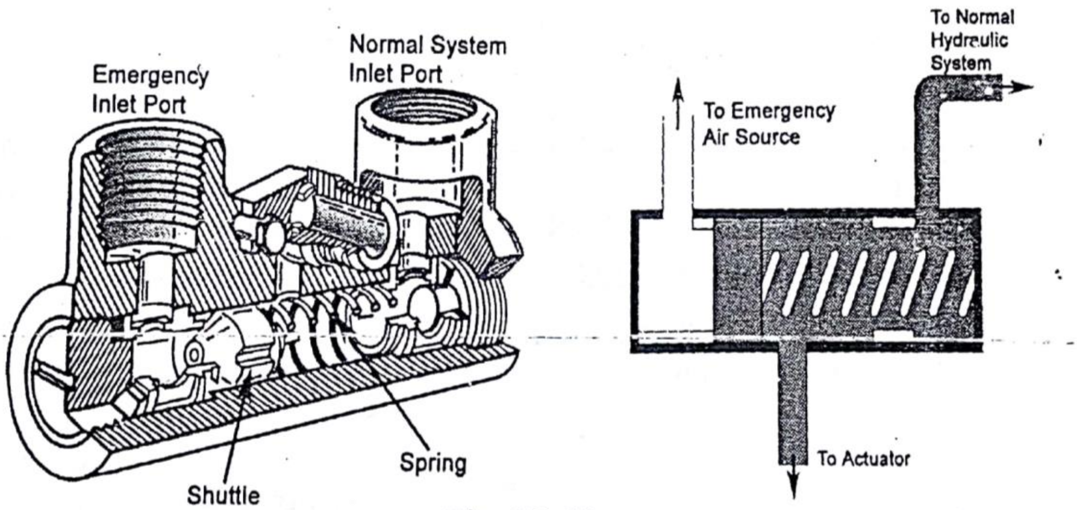


Fig. 28.10

5.4 Oxygen System

IMPORTANCE OF OXYGEN

A dependable supply of oxygen is an essential element for the containment of life. No one can live without sufficient quantities of food, water and oxygen. Of the three, oxygen is by far the most urgently needed. If necessary, a well-nourished person can go without food and water. However, the supply of oxygen in the body is limited to a few minutes. When this supply is exhausted, death is inevitable.

Oxygen starvation affects human beings in the same way as it affects an aircraft engine. Both the body and the engine require oxygen for burning of fuel. An engine designed for low altitude operation loses power and performs poorly at high altitudes. High altitude operation requires supply of air at higher pressure to give the engine enough oxygen for the combustion of fuel. A supercharger or compressor satisfies the engine demands. The combustion of fuel in a human body is the source of energy. As the aircraft climbs, the amount of oxygen per unit of volume decreases and the oxygen intake in the human body is reduced. Unless a person breathes additional oxygen, human organs begin to fail. The body is designed for low altitude operation and will not give satisfactory performance unless it is supplied with full amount of oxygen that it requires. Like engine, the body requires means of having this oxygen supplied to it in greater amounts or under greater pressure. This need is satisfied by use of supplemental oxygen supplied directly to the respiratory system through an oxygen mask and by pressurising the aircraft to a pressure equivalent to that at normal safe breathing altitudes or both.

CHARACTERISTICS OF OXYGEN

Oxygen in its natural state is a colourless, odourless and tasteless gas. Oxygen is considered to be the most important of all the elements to life. It forms about 21% of the atmosphere by volume and 23% by weight. The remainder of the atmosphere consists of nitrogen (78%) and inert gases (1%), of which argon is the most abundant. Of all the elements in our environment, oxygen is the most plentiful. It makes up nearly one-half of the earth's crust and approximately one-fifth of the air we breathe. Oxygen combines with most of the other elements. The combining of an element with oxygen is called oxidation. In almost all the oxidation reactions, heat is given off.

EFFECTS OF LACK OF OXYGEN

As the total atmospheric pressure decreases with altitude, the available oxygen pressure decreases in proportion. This necessitates supplemental oxygen. Lack of oxygen or oxygen deficit is referred to as hypoxia. When the body regains its normal oxygen supply, one may recover from hypoxia. A complete lack of oxygen, which results in permanent physical damage or death, is called anoxia.

Symptoms of hypoxia may begin at an altitude as low as 1,500 metres (5,000 feet) with decreased night vision. The retina of the eye is affected with extremely mild hypoxia. At 2,450 metres (8,000 feet), forced concentration, fatigue and headache may occur. At 4,250 metres (14,000 feet), forgetfulness, incompetence and indifference makes flying without the proper supplemental oxygen quite hazardous. At 5,200 metres (17,000 feet), serious handicap and collapse may occur. These effects do not necessarily occur in the same sequence or to the same extent in all individuals.

TYPES OF OXYGEN

Breathing oxygen (MIL-O-2721OD) for aircraft use is supplied in two types i.e. Type I and Type II. Type I is gaseous oxygen and Type II is liquid oxygen. Oxygen procured as per the above referred specification is 99.5% pure with water vapour content less than 0.02 milligrams per litre when tested at 21.1°C (70°F) and at sea level pressure.

Gaseous oxygen is stored in a high pressure steel cylinder under a pressure between 1800 to 2400 psi ($124x10^3$ to $166x10^3$ mb). Gaseous oxygen is mainly used in civil aircraft due to ease of handling.

Liquid oxygen systems are used in military aircraft due to small space requirements. However, on civil aircraft their use is limited due to special handling requirements of liquid oxygen. Liquid oxygen is a pale blue transparent liquid which remains in a liquid condition under standard pressure at a temperature of about -118°C (-180°F). To keep the oxygen in liquid form, it is stored in a vented Dewar bottle, which is a double walled steel container. The inner surface of the container is reflective, which minimises the transfer of heat by radiation. The air in between the walls is pumped out to minimise the transfer of heat by conduction.

Technical oxygen, both gaseous and liquid, meets the specification BB-O-925A. The moisture content of technical oxygen is not as rigidly controlled as in case of breathing oxygen. Therefore, the technical grade is not used in aircraft oxygen systems.

The extremely low moisture content required for breathing oxygen is not to avoid physical injury to the body, but to ensure proper operation of the oxygen system. Air containing a high percentage of moisture can be breathed indefinitely without any serious ill effects. The moisture affects the aircraft oxygen system in the small orifices and passages in the regulator. Freezing temperatures can clog the system with ice and prevent oxygen from reaching the user. Therefore, extreme precautions must be taken to safeguard against the hazards of water vapour in oxygen systems.

OXYGEN SYSTEM REQUIREMENTS

Pressurised aircraft normally cruise at altitudes where cabin pressurisation is necessary to maintain the cabin equal to a maximum altitude of 2,450 metres (8,000 feet) regardless of actual altitude of the aircraft. Under such conditions, oxygen is not normally needed for the comfort of the passengers and the flight crew. However, as a precaution, oxygen system is installed for use in the event of pressurisation failure.

Regulations require flight crew to use oxygen on flights of 30 minutes duration above 3,800 metres (12,500 feet) and at all times above 4,250 metres (14,000 feet). The oxygen requirement is of the order of one litre per minute for every 3,050 metres (10,000 feet). For example at 5,500 metres (18,000 feet), the oxygen requirement is 1.8 litres per minute through standard breathing equipment. The passengers should also have supplemental oxygen available over 4,600 metres (15,000 feet). However, during night the use of supplemental oxygen is recommended at altitudes over 1,500 metres (5,000 feet).

The flight crew oxygen system is a high pressure gaseous system. The passenger oxygen system uses chemical oxygen generators. With this categorisation in view, the oxygen system falls into following configurations:

- Continuous flow up to 7,600 metres (25,000 feet) for both passengers and flight crew.
- Diluter demand up to 12,200 metres (40,000 feet) widely used for flight crew particularly in large transport aircraft.
- Pressure demand above 12,200 metres (40,000 feet).
- Chemical oxygen generator system.

General description of flight crew oxygen system is shown in Fig. 30.1.

Continuous Flow Oxygen System

The continuous flow oxygen system allows a metered amount of oxygen to continuously flow into the mask. A rebreather type mask is used with continuous flow system. The simplest form of continuous flow system regulates the flow through a calibrated orifice in the outlet to the mask. Continuous flow system supplies oxygen continuously. As such, there are chances of wastage. The system can be used up to 5,500 metres (18,000 feet) with a cannula and 7,600 metres (25,000 feet) with a mask.

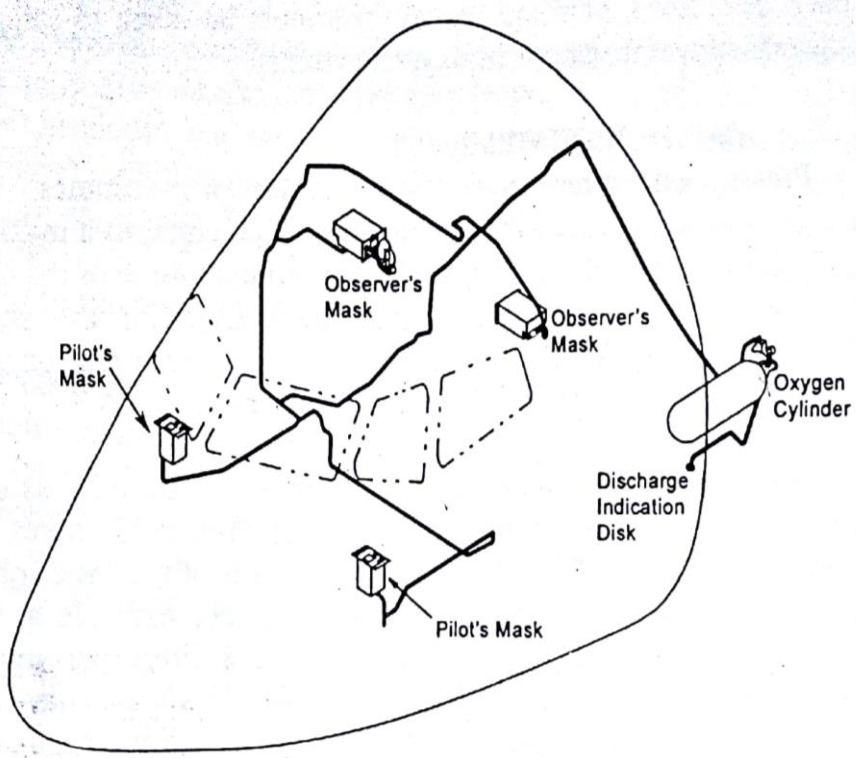


Fig. 30.1

Unpressurised aircraft flying at higher altitudes may have continuous flow oxygen system for the passengers and diluter demand oxygen system for the flight crew.

A typical continuous flow oxygen system is shown in Fig. 30.2. The oxygen is carried in a high pressure steel cylinder. The pressure is reduced from that in the cylinder to 300-400 psi ($21x10^3$-$28x10^3$ mb) by the pressure reducing valve. The oxygen supply is metered by the pressure regulator before it is delivered to the masks. A pressure relief valve protects the oxygen cylinder from over pressure. If an over pressure condition occurs, the oxygen will flow overboard. This flow will blow out a green indication disk on the aircraft fuselage.

Diluter Demand Oxygen System

In a diluter demand oxygen system, the oxygen is metered to the mask where it is diluted with cabin air by an airflow metering assembly referred to as diluter demand regulator, which regulates the amount of air to be diluted on the basis of cabin altitude. The mixture of oxygen and air flows only when a person inhales through the mask. Thus the wastage is minimum. Diluter demand systems sense altitude and supply the appropriate amount of oxygen.

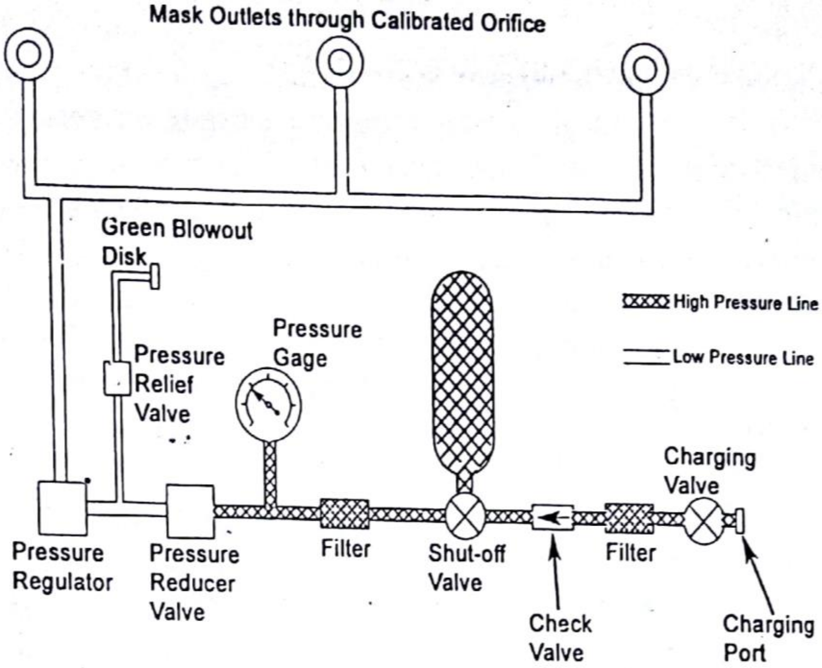


Fig. 30.2

Almost all pressurised turbine engined aircraft have a diluter demand oxygen system for the flight crew and the continuous flow system for the passengers. A typical diluter demand oxygen system is shown in Fig. 30.3.

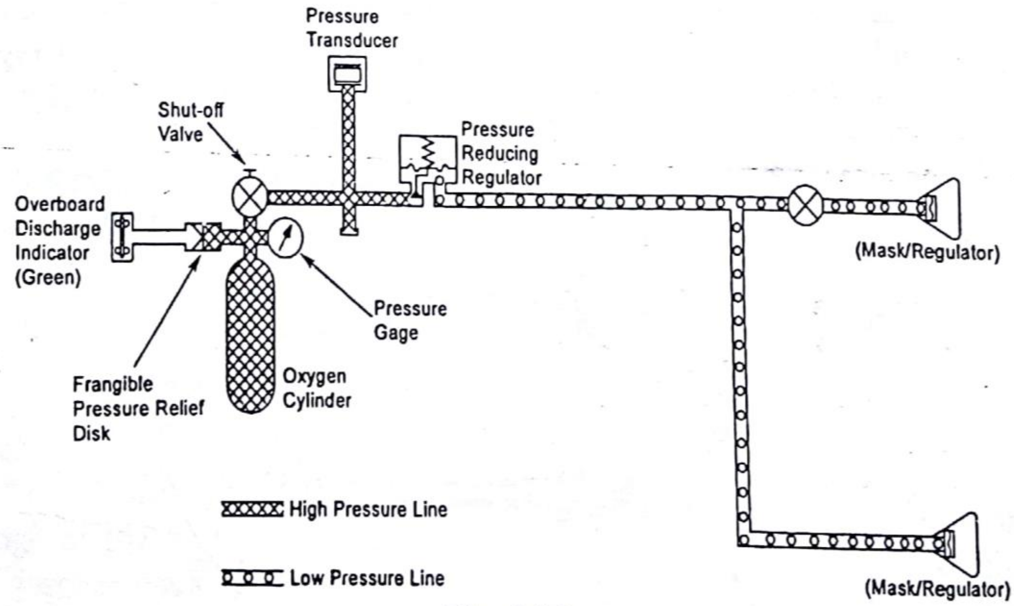


Fig. 30.3

Pressure Demand Oxygen System

The pressure demand oxygen system is used on aircraft that fly at very high altitudes. Pressure demand systems supply oxygen to the mask at higher than ambient pressures. The system functions in a similar way as the diluter demand type until at about 12,200 metres (40,000 feet) the output to the mask is pressurised enough to force the needed oxygen into the lungs.

Chemical Oxygen Generator System

In the chemical oxygen generator system, oxygen is produced by the chemical generator and dispenser units. The passenger oxygen system uses chemical oxygen generators to make oxygen. The generators are located in the passenger service units. Each chemical generator is separate and supplies to individual masks. The masks are connected to the chemical generators by flexible tubes. Oxygen from the generators flows through flexible hoses to the passenger oxygen masks. A typical chemical oxygen generator system is shown in Fig. 30.4.

The oxygen generators are metal-cased cylindrical devices. A spring-loaded firing mechanism is at one end of the generator. An output manifold and a relief valve are at the other end. The oxygen generators make oxygen by a chemical reaction. Sodium chlorate mixed with the binding material is moulded into a solid block. The block is installed in an insulated stainless steel case. In the reaction, sodium chlorate and iron react to make salt and gaseous oxygen. After the reaction starts, it cannot be stopped. The reaction continues until all the sodium chlorate is used. The reaction produces heat, which increases the generator surface temperature to around 232°C (450°F). The gaseous oxygen goes through a filter medium and then flows out of the output manifold. The output manifold ports connect to the passenger oxygen masks by flexible tubing. A pressure relief valve prevents over pressurisation of the generator.

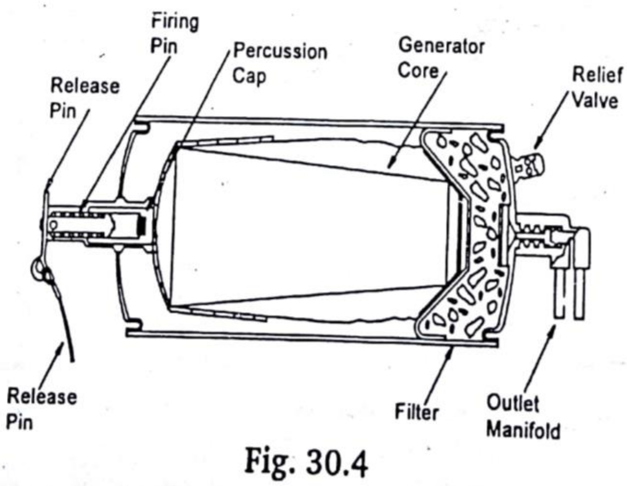


Fig. 30.4

Portable Oxygen System

Portable oxygen cylinders are used for first aid purpose. Each portable oxygen cylinder is a separate system. The oxygen is stored in a steel cylinder under high pressure of 1800 psi ($124x10^3$ mb) at 21°C (70°F). The cylinders are charged with dry aviation grade oxygen. An indicator on the cylinder shows cylinder pressure (quantity of oxygen available). A shut-off valve on the cylinder head controls the flow of the high pressure oxygen to the cylinder head assembly. Cylinder head components regulate oxygen pressure and flow to the attached mask(s). When the shut-off valve is open, the cylinder supplies oxygen to two constant flow outlets. The outlet fittings have glass cord metering devices and check valves. The check valves are unseated by the mask connector to allow flow when a mask is connected. A typical portable oxygen cylinder is shown in Fig. 30.5.

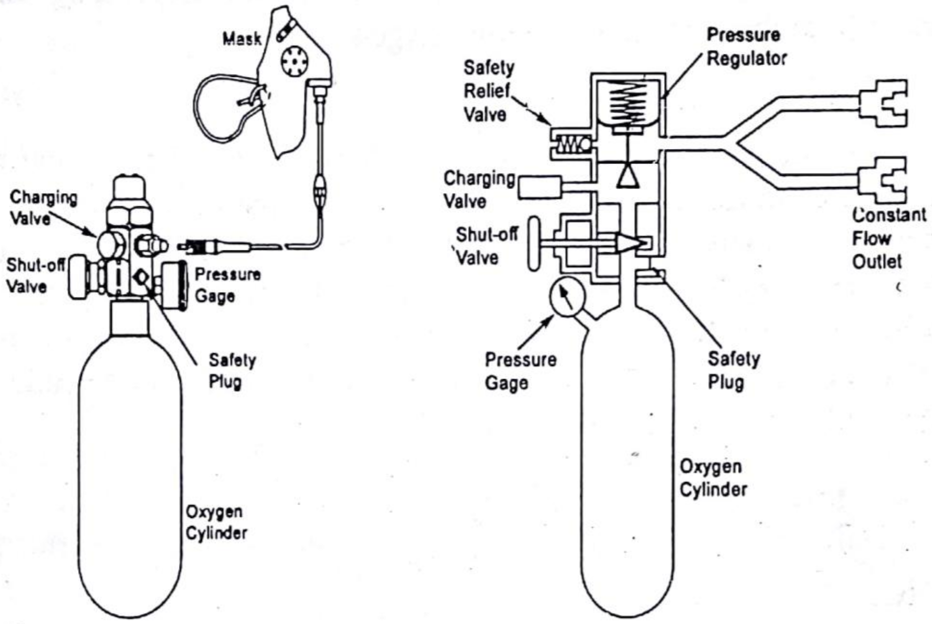


Fig. 30.5

OXYGEN SYSTEM COMPONENTS

Basically, all gaseous oxygen systems consist of a cylinder to store oxygen, regulators to reduce the pressure from high pressure in the cylinder to low pressure required for breathing, plumbing and masks to deliver the oxygen to the flight crew and/or passengers.

Cylinders

Gaseous oxygen cylinders are generally high pressure type. The main advantage of the high-pressure cylinder is that it minimises space used for storing gaseous oxygen. All high-pressure oxygen cylinders are painted green in accordance with the established colour codes provided in MIL-STD-01A.

Diluter Demand Type Regulator

A diluter demand regulator dilutes the oxygen supply to the mask with air from the cabin. The air enters the regulator through the inlet air valve. At low altitudes, the air inlet passage is open and the passage to the oxygen demand valve is restricted so that the occupant gets mostly air from the cabin. As the altitude of aircraft increases, the barometric control bellows expands and opens the oxygen passage while closing the air passage. At an altitude of around 10,650 metres (35,000 feet), the air passage is completely closed and every time the occupant inhales, pure oxygen is metered to the mask.

Pressure Demand Regulator

A pressure demand regulator is similar to the diluter demand regulator. However, at altitudes above 12,200 metres (40,000 feet), it supplies oxygen to the mask under a low positive pressure rather than depending on the low pressure from the lungs to pull in the oxygen.

Continuous Flow Regulator

Continuous flow regulators are both automatic and manual type. The automatic continuous flow regulator has a barometric control valve, which automatically adjusts the flow of oxygen to correspond with the altitude. The manual regulator has a control that allows the flight crew to adjust the flow of oxygen based on the altitude. The regulator meters the correct amount of oxygen for a selected altitude. However, with the change in altitude, the flow of oxygen is required to be readjusted.

Breathing Devices

Different types of breathing devices are explained in the following paras.

Face Masks

There are two types of face masks namely the partial rebreather and the sequential breather. The partial rebreather type has an external plastic bag. This type usually has a very flexible face mask construction that is somewhat fragile and easy to distort when subjected to excessive heat. The mask design works effectively well below the altitudes of 7,600 metres (25,000 feet) if installed properly on the face. This type of mask should not be used above 7,600 metres (25,000 feet) because it does not have a positive seal against the face.

The sequential rebreather mask has a check valve system that efficiently allows the induction of oxygen and outside air into the mask. It then allows a person to breath. Under ideal conditions this type of mask can be used up to 12,200 metres (40,000 feet).

Rebreather type of mask is used with continuous flow oxygen system (Fig. 30.6). The oxygen mask, which automatically drops from the overhead bins of a large transport aircraft in the event of cabin depressurisation, is of rebreather type.

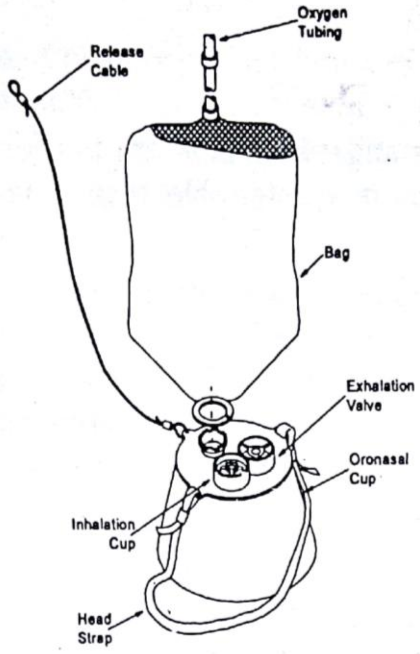


Fig. 30.6

The flight crew oxygen masks are diluter/demand masks. In the demand mode, a mask regulator supplies oxygen to the crew member only when it is inhaled. In the diluter mode, cabin air mixes with oxygen. An aneroid metering valve in the mask controls this function. The mixture of air and oxygen is proportional to the cabin pressure altitude. A typical flight crew oronasal mask is shown in Fig. 30.7.

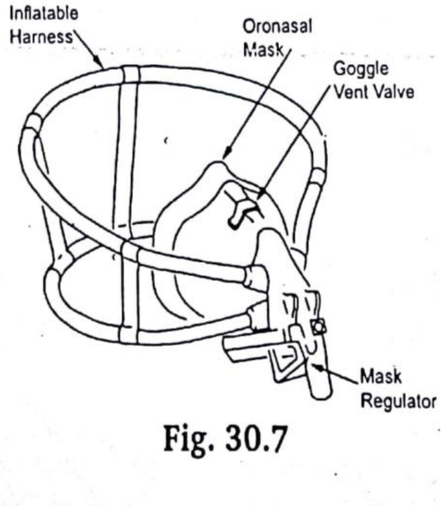


Fig. 30.7

Standard Cannulas

The medical cannula breathing device has been successfully adapted for use on the aircraft. The cannula breathing device can be used satisfactorily up to 5,500 metres (18,000 feet). One of the reasons for restricting its use above 5,500 metres (18,000 feet) is due to problems controlling the exhalation of carbon dioxide (CO_2). Below 5,500 metres (18,000 feet), the control or regulation of CO_2 into the lungs is not too critical.

The oxygen required for the standard cannula is the same as a face mask (1 litre per minute for every 3,050 metres or 10,000 feet). The advantages of the standard cannula are freedom to talk, eat and drink. The cannula is much more comfortable than a face mask, especially for long durations.

5.5 Environmental control system

Air conditioning system

- Air cycle cooling system
- Freon vapor cycle cooling systems

Aircraft pressurization system

Atmospheric Considerations

As the aircraft became capable of obtaining altitudes above that at which flight crew could operate efficiently, a need arose for complete environmental systems.

Pressurisation and air conditioning of aircraft are necessary at high altitudes. This is done be sealing off the entire cabin/cockpit and any equipment area that may require pressurisation and maintaining an inside air pressure equivalent to that at substantially lower altitudes. This is known as the pressurised cabin, cockpit, or compartment, as applicable.

In addition to pressurising, the cabin, cockpit and some compartments are also air conditioned for aircraft flying at high speeds. The factors affecting cabin/cockpit temperature are the aerodynamic heating, engine heat, solar heating, heat produced by the electrical units and heat from the human body. Through research and tests, it was determined that the average total temperature of these five heat sources will raise the cabin/cockpit temperature to approximately 88°C (190°F). Through experiments, it was determined that the maximum temperature that a person can withstand and maintain efficiency for extended periods is 27°C (80°F). Therefore, air conditioning of the cabin/cockpit area is just as essential as the pressurisation. Under low speed operating conditions at low temperature, cabin/cockpit heating may be required.

The proper operation of aircraft electronic equipment is also dependent on maintaining a reasonable operating temperature that will prolong the life of various components. In most cases, equipment cooling is provided by a ducting from the cabin/cockpit system. Another method is to have a separate cooling system dedicated for equipment cooling.

The combined pressurisation and air conditioning of the cabin is the function of the aircraft pressurisation and air conditioning system. The environmental control systems of most aircraft include cabin air conditioning and pressurisation system. Salient requirements necessary for the successful functioning of an environmental control system are as follows:

a) The cabin may be designed to withstand the necessary pressure differential.

b) A means of limiting the maximum pressure differential to which the cabin will be subjected.

c) The aircraft must have an adequate supply of compressed air. This is provided through the compressor section of a turbine engine. A separate compressor or supercharger is used on aircraft having reciprocating engines.

d) A means of cooling the bleed air before it enters the cabin.

e) A means of regulating the pressure and rate of pressure change in the cabin.

f) A means of controlling the cabin pressure.

AIR CONDITIONING SYSTEM

Air conditioning system is used to cool air inside the aircraft for the comfort of its occupants. There are following two basic methods of cooling the cabin air:

- Air cycle cooling systems
- Freon vapour cycle cooling systems

Air cycle cooling systems are used on modern large turbine engined aircraft. These systems use the compression and expansion of air to adjust the temperature in passenger and crew compartments.

The vapour cycle cooling systems are used on reciprocating engine aircraft and in some small turboprop aircraft. This is a closed system that uses the evaporation and condensation of freon to remove heat from the cabin.

Air Cycle Cooling System

The name air cycle comes from the principle of cooling the air without the use of refrigerants by compression and expansion of hot bleed air. Air is by nature the safest and cheapest refrigerant. Air cycle systems have specific advantages that apply to all potential applications:

- The working fluid (air) is free, environmentally benign, totally safe and non-toxic.
- The performance of an air cycle system does not deteriorate as much as that of a vapour cycle system when operating away from its design point.

The use of air as a refrigerant is based on the principle that when a gas expands isentropically from a given temperature, its final temperature at the new pressure is much lower. The resulting cold gas, i.e. air, can then be used as a refrigerant, either directly in an open system or indirectly by means of a heat exchanger in a closed system. The efficiency of such a system is limited to a great extent by the efficiencies of compression and expansion as well as those of the heat exchangers employed.

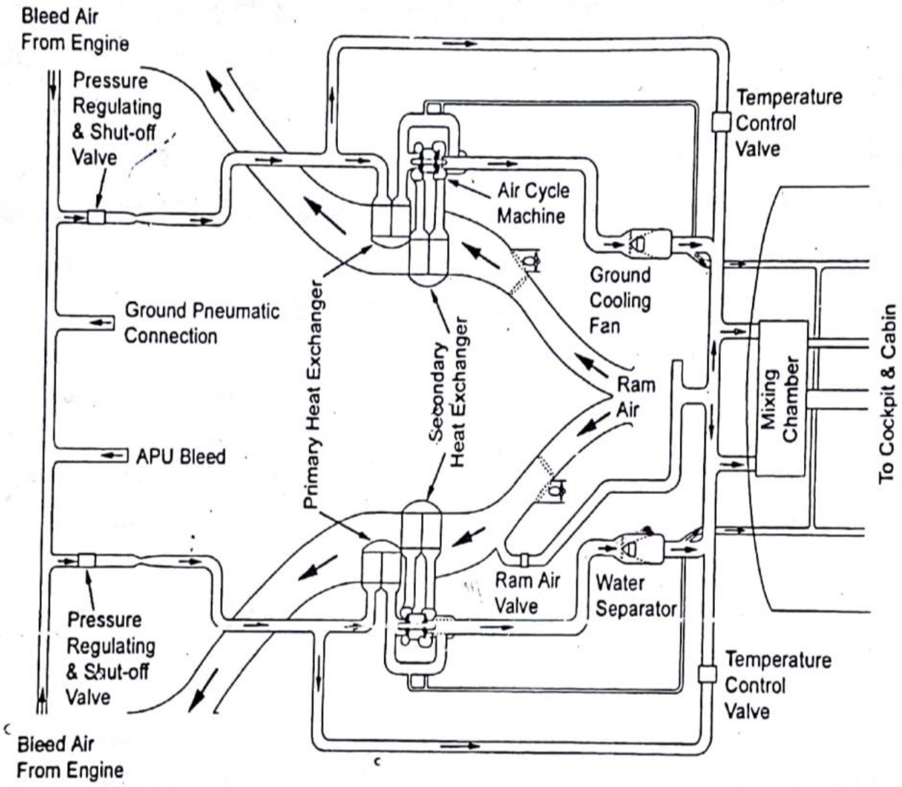


Fig. 31.1

System Operation

The air cycle system utilises hot bleed air from the engine, which passes through the primary heat exchanger. The cold ram air, forced across the heat exchanger by the forward motion of the aircraft, absorbs heat from the bleed air thereby reducing its temperature. The air after leaving the primary heat exchanger enters the compressor end of the air cycle machine where both the temperature and pressure of air increases. The compressed air enters the secondary heat exchanger where ram air absorbs the heat gained through compression. After leaving the secondary heat exchanger, the cool high pressure air gives up much of its energy in rotating the expansion turbine, which drives the air cycle machine compressor. This results in the reduction of pressure also. The decrease in pressure and extraction of energy to drive the compressor results in large decrease in air temperature. The rapid cooling of air causes moisture to condense. As the air passes through a moisture separator, the water gets collected there. To prevent the water from freezing, it is mixed with warm air in the separator. A temperature sensor at the outlet of the water separator regulates the temperature control valve. If the temperature of the air at the outlet of the water separator falls below 3.3°C (38°F), the control valve opens allowing the warm air to mix with air in the water separator. The air cycle machine along with its associated systems is referred to as a pack. A generalised air cycle system is shown in Fig. 31.1.

As enumerated above, the aircraft air conditioning systems often use the work of expansion to assist the compression process, which is referred to as bootstrap system (Fig. 31.2). This means that heat is removed by expansion process and is converted into work to drive the compressor.

Air Cycle Cooling System Components

Flow Control Shut-off Valve or Pack Valve

The flow control shut-off or pack valve is used to control the flow of air in the system. After the bleed air goes through the flow control shut-off valve, it enters the primary heat exchanger. Depending upon the demand, the valve can either shut-off or modulate the air flow required for air conditioning.

The valve is electrically controlled and pneumatically actuated. It is spring loaded to the closed position.

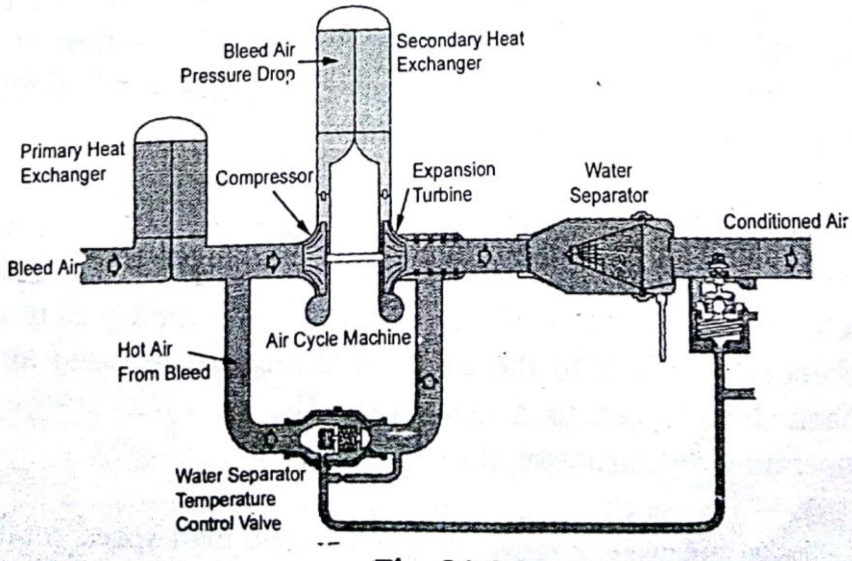


Fig. 31.2

Primary Heat Exchanger

The primary heat exchanger receives bleed air from the flow control shut-off valve. As the bleed air goes through the heat exchanger, ram air removes the heat. The cooled bleed air goes to the compressor section of the air cycle machine. The primary plenum/diffuser lets ram air flow through the primary heat exchanger to the ram air exhaust. The primary plenum/diffuser has an outer duct and an inner duct. The outer duct is the plenum and the inner duct is the diffuser (Fig. 31.3).

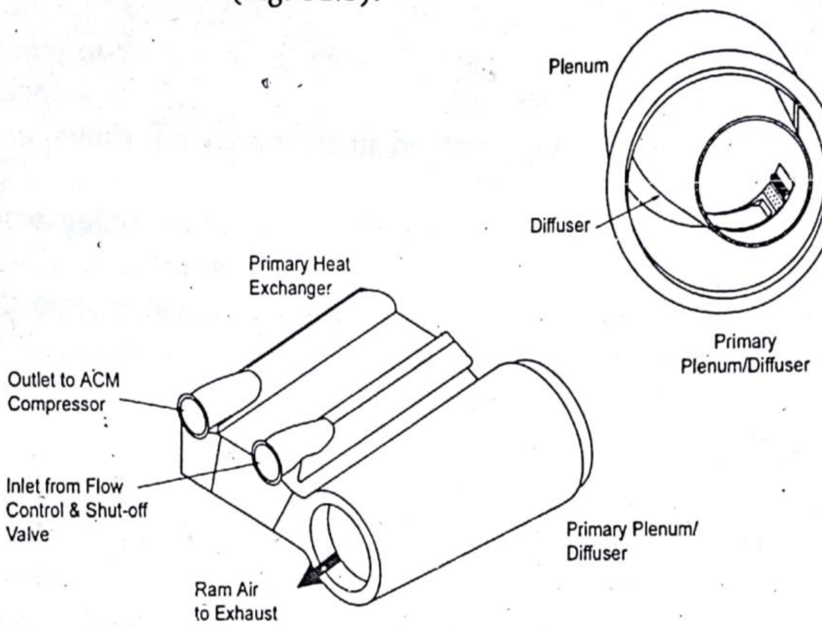


Fig. 31.3

The primary heat exchanger is an air-to-air, plate-fin and cross-flow type heat exchanger. The primary heat exchanger works on the same principle as the radiator in an automobile. The cold ram air passes to cool the hot engine bleed air. The heat exchanger has fin like tubes. As the cold ram air passes over these tubes, the bleed air gets cooled. The flow of ram air through the heat exchanger is controlled by moving inlet and exit doors that modulate in flight to provide the required cooling.

Air Cycle Machine

Cooled bleed air from the primary heat exchanger enters the air cycle machine and is compressed. The compressed air then goes to a secondary heat exchanger and back to the air cycle machine. The bleed air is then rapidly expanded and goes to a condenser. The air cycle machine decreases air temperature, by expansion through a turbine.

The air cycle machine (Fig. 31.4) is a high speed rotating assembly. It has following three sections connected by a common shaft:

- Turbine,
- Compressor, and
- Impeller Fan.

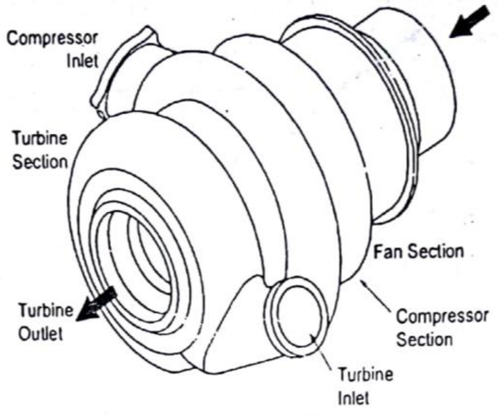


Fig. 31.4

Secondary Heat Exchanger

The secondary heat exchanger (Fig. 31.5) receives compressed air from the air cycle machine. As the air goes through the heat exchanger, ram air removes heat. A cross flow of ram air removes heat before the air enters the air cycle machine turbine inlet. After the compressed air is cooled, it goes through a water extractor duct and back to the air cycle machine. The secondary plenum/diffuser lets ram air flow through the secondary heat exchanger to the ram air exhaust. As in the case of primary heat exchanger, the secondary plenum/diffuser also has an outer duct and an inner duct referred to as the plenum and the inner duct respectively.

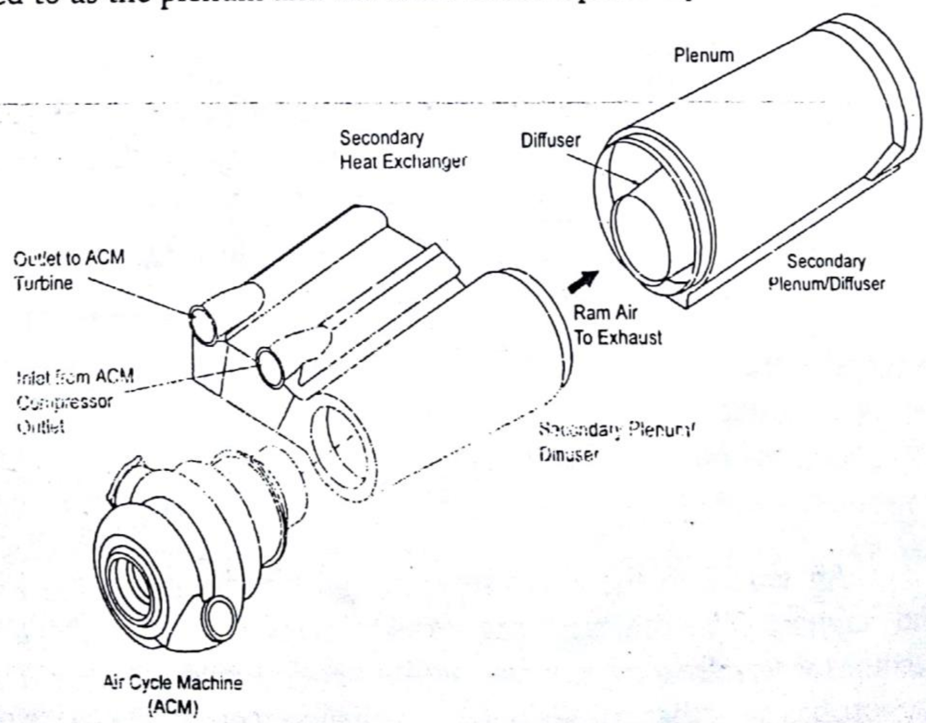


Fig. 31.5

The secondary heat exchanger is also an air-to-air, plate fin and counter-flow type. Air exiting from primary heat exchanger is routed to the compressor side of the air cycle machine. The compressor raises both temperature and pressure of the air. Warm and high pressure air then passes through the secondary heat exchanger, which provides additional cooling. It operates in the same manner as the primary heat exchanger.

Ram Air System

The ram air system controls the air flow through the primary and secondary heat exchangers. There are following two sets of ram air ducts for each pack system:

- Ram air inlet
- Ram air exhaust

The ram air inlet ducts let cooling air flow from the ram air inlet to the heat exchangers. The ram air exhaust ducts let air flow from the heat exchangers discharge overboard.

Water Separator

The rapid cooling of air in the turbine causes moisture to condense in the form of water droplets. The cold air from the air cycle machine can contain moisture (atomised water mist). The water separator collects and removes moisture from the air before it goes into the distribution system (Fig. 31.6).

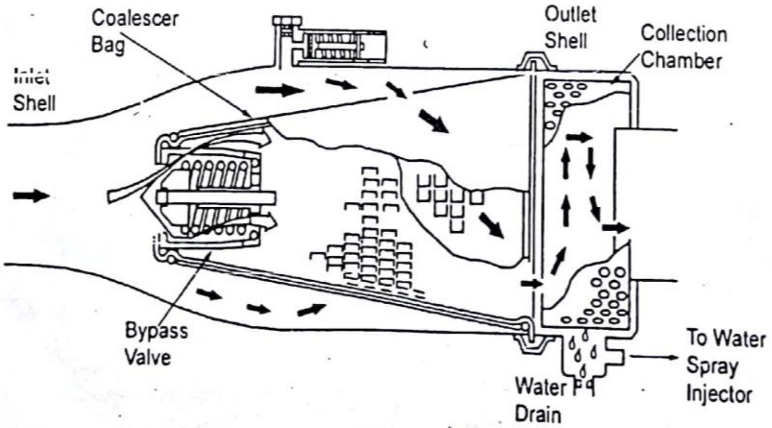


Fig. 31.6

Air goes into the water separator inlet and through the coalescer bag and support. The coalescer bag collects water mist from the air. The mist becomes water droplets as more moisture goes through the bag. The coalescer support has slots that move the air in a circular motion. The air with the water droplets moves around the internal part of the coalescer support to the collection chamber. The collection chamber is a baffle that causes the water and air to make a sharp bend out of the outlet shell. This separates the heavier water droplets while the air moves out freely.

A functional description of air cycle cooling system for a large turbine engined aircraft is shown in Fig. 31.7.

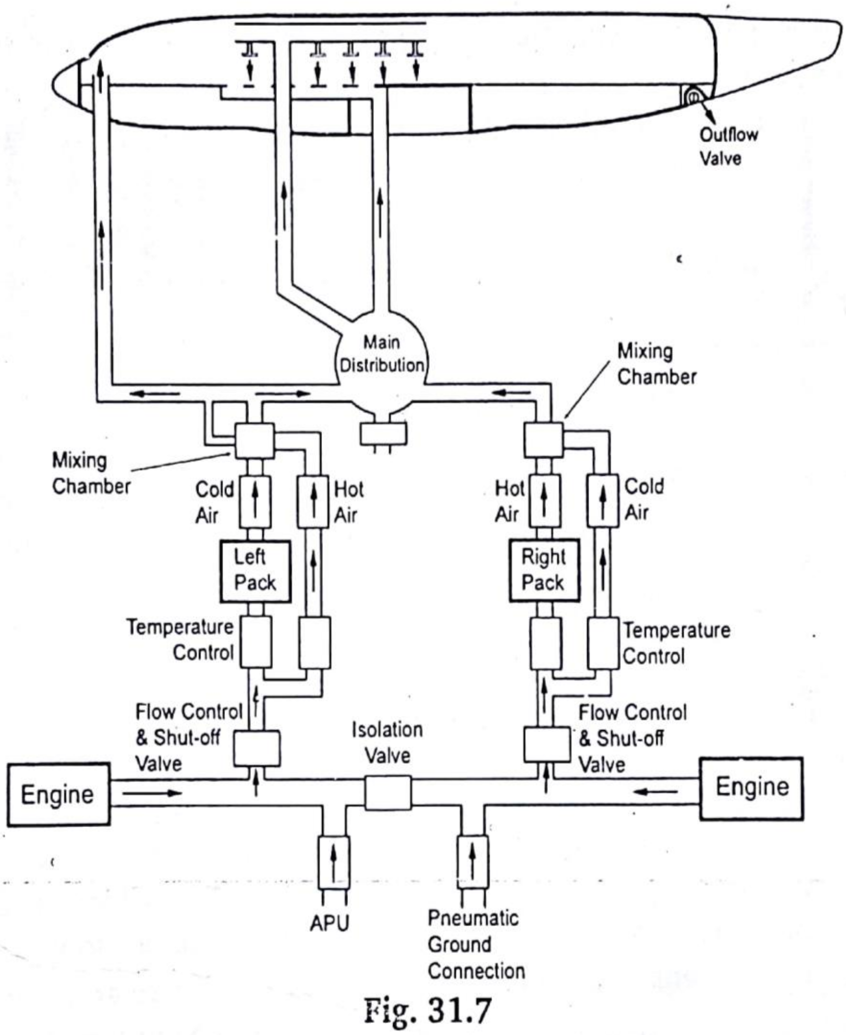


Fig. 31.7

Vapour Cycle System

Vapour cycle cooling system makes use of the fact that a liquid can be vaporised at any temperature by changing the pressure above it. Water at a sea level pressure of 14.7 psi (1013.2 mb) will normally boil at 100°C (212°F). However, if the water in enclosed in a container and pressure reduced below 14.7 psi (1013.2 mb), it would boil at a lower temperature. As we keep on reducing pressure, the boiling temperature of water will also keep on decreasing gradually. Thus water can be made to boil at any temperature if the pressure corresponding to the desired boiling temperature can be maintained. Liquids that boil at low temperatures are most desirable for use as refrigerants. The principle of vapour cycle cooling is based on the ability of a refrigerant to absorb the heat in the process of changing from liquid to gas. Comparatively large quantity of heat is absorbed when liquids are evaporated. In an aircraft, the refrigerant changes from liquid to vapour and in doing so absorb the heat from the cabin. As this heat is taken out from the aircraft, the refrigerant returns to liquid state.

The vapour cycle cooling system is a closed loop system where the heat is absorbed by the evaporation of the liquid refrigerant in an evaporator. The refrigerant then passes through a compressor with a corresponding increase in pressure and temperature, before being cooled in a condenser where the heat is rejected to a heat sink.

From the law of conservation of energy, we know that heat is a form of energy, which can neither be created nor destroyed. It continues to exist irrespective of its state. Heat flows from one object having a certain level of energy into an object having a lower level of energy. The refrigerant used in an aircraft air conditioning system is a liquid under certain conditions. When the refrigerant is surrounded by air having higher level of heat energy, it absorbs the heat and changes from liquid state to gaseous state. The air that gives up its heat to the refrigerant is cooled in the process.

System Operation

The system is divided into two sections – one that accepts the heat and the other that releases it. The section, which accepts the heat, is referred to as low side because the refrigerant is at low temperature and pressure. The section from where heat is released is referred to as high side because the refrigerant is at high temperature and pressure. The system is divided at the compressor. The portion containing evaporation is low side and that containing condenser is high side.

In refrigeration circuit, liquid flows from the receiver dryer to the thermal expansion valve. The compressor maintains a difference in pressure between the evaporator and the condenser. The purpose of thermal expansion valve is to maintain this difference in pressure and separates the high pressure and low pressure parts of the system. It also functions as a pressure reducing valve because the pressure of the liquid flowing through it is lowered. Only a small quantity of the refrigerant flows through the valve into the evaporator. The valve is adjusted in such a way that only calculated amount of liquid that can be vaporised in the evaporator passes through it. The liquid that flows through the evaporator gets vaporised completely by the heat flowing through the walls of the evaporator.

After leaving the evaporator, the vaporised refrigerant flows through the compressor. Its pressure is increased to a point which is sufficient for condensation. After being compressed, the vapour flows to the condenser. The walls of the condenser are cooled by either water or air. As a result the vapour is liquefied. Heat is transferred from the condensing vapour to the water or air through the walls of the condenser. From the condenser the liquid refrigerant flows back to the receiver dryer and the cycle is then repeated. A typical vapour cycle cooling system is shown in Fig. 31.8.

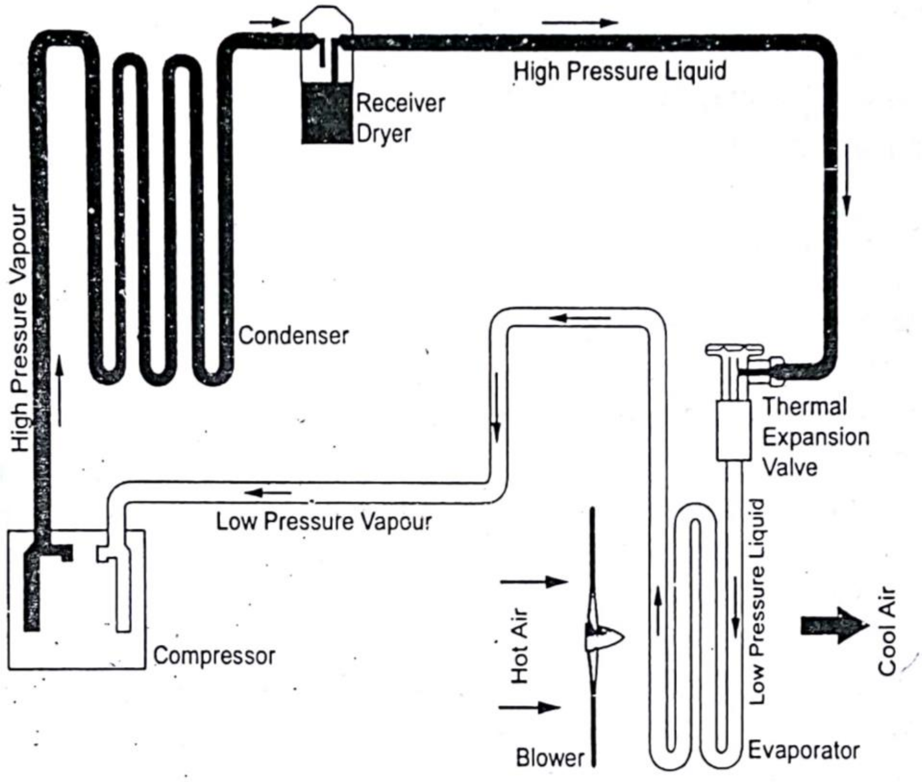


Fig. 31.8

The refrigerant must be delivered to the evaporator in liquid state to absorb large quantities of heat. Since it leaves the evaporator in vapour state, some way of condensing the vapour is necessary. To condense the vapour, heat given up by the vapour during condensation must be transferred to some other medium. For this purpose, water or air is usually used. The water or air must be at a temperature lower than the condensing temperature of the refrigerant. At any given pressure, the condensing and vaporising temperature of a fluid are the same. To condense the vapour, its pressure must be increased to a point that its condensing temperature will be above the temperature of the water or air available for condensing purposes. For this purpose a compressor is required. After the pressure of the refrigerant vapour has been increased sufficiently, it may be liquefied in the condenser with comparatively warm water or air.

Vapour Cycle Cooling System Components

Refrigerant

Any volatile liquid can be used as a refrigerant. However, for maximum effectiveness, the liquid must have a very low vapour pressure and low boiling point. The vapour pressure of a liquid is the pressure that exists above a liquid in an enclosed container at any given temperature. For aircraft air conditioning system, dichlorodifluoromethane is almost universally used. It is a stable compound at low and high temperatures and does not react with any component of the air conditioning system. Dichlorodifluoromethane is available under different trade names viz. Freon 12, Genetron 12, Isotron 12, Ucon 12, etc. Freon 22 is also similar to Freon 12, however, its use is limited to commercial applications.

Receiver Dryer

The receiver dryer removes moisture from the system. It acts as a reservoir of the system to hold the supply of the refrigerant until it is needed by the evaporator. It is located between the condenser and the thermal expansion valve. Liquid refrigerant enters the receiver dryer from the condenser. It is filtered and passes through desiccant to absorb any moisture present in the system (Fig. 31.9). The desiccant used is silica gel. If moisture remains in the system, the low temperatures in the system may cause it to freeze thereby leading to clogging.

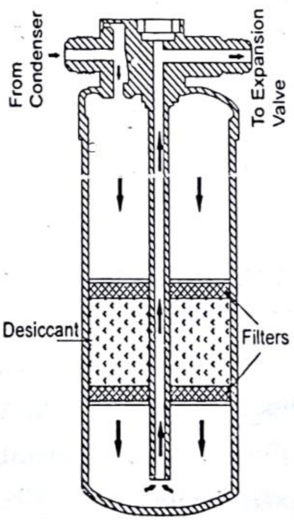


Fig. 31.9

Condenser

The condenser in a vapour cycle cooling system receives the hot and high pressure refrigerant vapours from the compressor. It transfers the heat from the refrigerant vapours to the air flowing over the condenser coils. After the heat is removed, the refrigerant turns into liquid state.

Evaporator

Evaporator is that part of the air conditioning system where the cold air is produced. The function of the evaporator is to lower the cabin air temperature. In the evaporator, heat is absorbed by the refrigerant. In the process the refrigerant changes from liquid to vapour state.

Thermal Expansion Valve

The thermal expansion valve is a control device, which meters the correct amount of refrigerant into the evaporator. The entire liquid refrigerant must turn into vapour by the time it gets to the end of the evaporator coil. A typical thermal expansion valve is shown in Fig. 31.10. It consists of a housing containing inlet and outlet ports. The flow of refrigerant to the outlet port is controlled by the positioning of needle valve. The valve position is controlled by the pressure created by the sensor, the superheat spring setting and the evaporator discharge pressure.

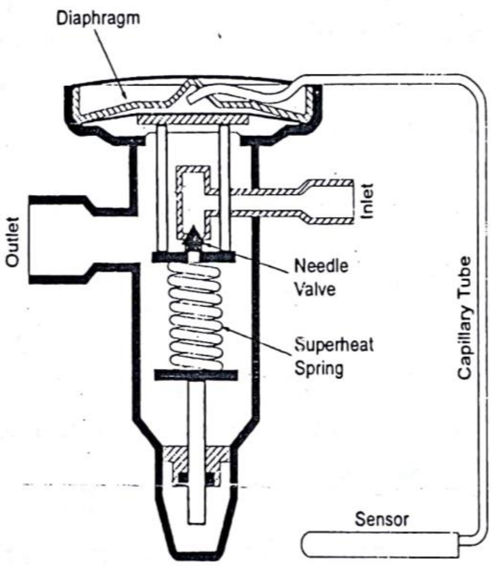


Fig. 31.10

The sensor is filled with the refrigerant and is attached to the evaporator. Pressure within the sensor corresponds to the refrigerant pressure leaving the evaporator. This force is felt on top of the diaphragm. Any increase in pressure causes the valve to move to open position. The superheat spring is designed to control the amount of superheat in the gas leaving the evaporator.

AIRCRAFT PRESSURISATION SYSTEM

Flying at high altitudes is more fuel efficient and it allows the aircraft to fly above the undesirable weather conditions. When the aircraft is flown at a high altitude, it consumes less fuel for a given airspeed than it does for the same speed at a lower altitude. However, at such high altitudes the oxygen

5.6 Fuel System

The purpose of an aircraft fuel system is to store and deliver proper amount of clean fuel at the correct pressure to the aircraft engine. In large aircraft, the fuel system supplies fuel to the Auxiliary Power Unit (APU) also. Fuel system should provide positive and reliable fuel flow through all phases of flight including:

- Changes in altitude,
- Violent manoeuvres, and
- Sudden acceleration and deceleration.

The fuel system should also continuously monitor system operation such as fuel pressure, fuel flow, warning signals and tank quantity. It should also be free from any tendency of vapour lock. Fuel systems are classified in following two broad categories according to the method used to feed fuel to the engine from the fuel tanks:

- Gravity feed system
- Pressure feed system

GRAVITY FEED SYSTEM

Gravity feed systems use only the force of gravity to transfer the fuel from the tanks to the engine. The bottom of the fuel tank must be high enough to provide adequate pressure to the fuel control component. This type of system is often used in a high-wing light aircraft.

The system normally comprises two fuel tanks. The outlets from the tanks are connected to the selector valve, which helps to draw the fuel either from separate tanks or from both the tanks together. The space above the tanks is interconnected and vented outside of the aircraft. After leaving the selector valve, the fuel passes through the strainer and to the carburettor inlet. Fuel for the primer is drawn from the strainer. A typical gravity feed fuel system is shown in Fig. 32.1.

PRESSURE FEED SYSTEM

If the design of aircraft is such that gravity cannot be used to transfer fuel, fuel pumps are installed. Pressure feed systems require the use of a fuel pump to provide fuel pressure to the engine's fuel control component. An engine driven or electric pump is normally used to provide adequate fuel pressure. A simplified pressure feed fuel system is shown in Fig. 32.2.

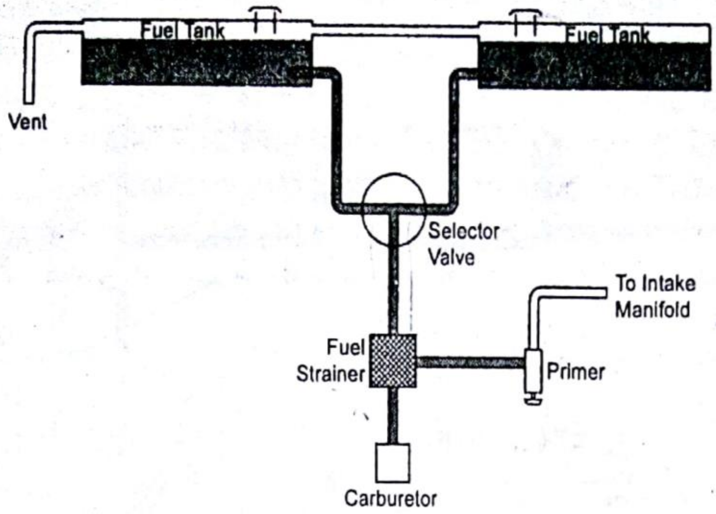


Fig. 32.1

Main reasons for use of pressure feed system are as follows:

- The fuel tanks are too low to provide enough pressure by gravity.
- The fuel tanks are located at a greater distance from the engine.

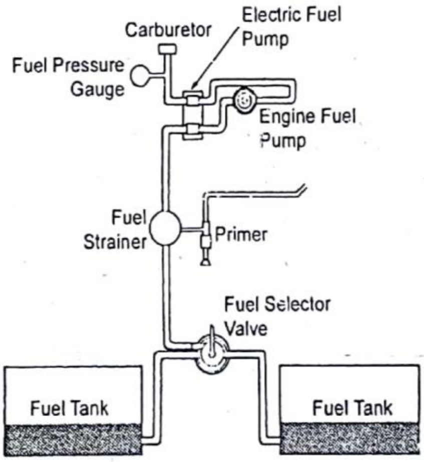


Fig. 32.2

Also, large transport aircraft fitted with high powered engines require a pressure system regardless of the fuel tank location because of the large volume of fuel used by the engines.

A generalised fuel system of large transport aircraft is shown in Fig. 32.3. The fuel tanks are installed on the wings and the fuselage to store fuel for use by the engines. The pressure fuelling system enables to add fuel into each tank. Defuelling and fuel transfer is carried out at the fuelling station. Same fuel system is by and large applicable to twin engined turboprop aircraft without APU fuel feed line.

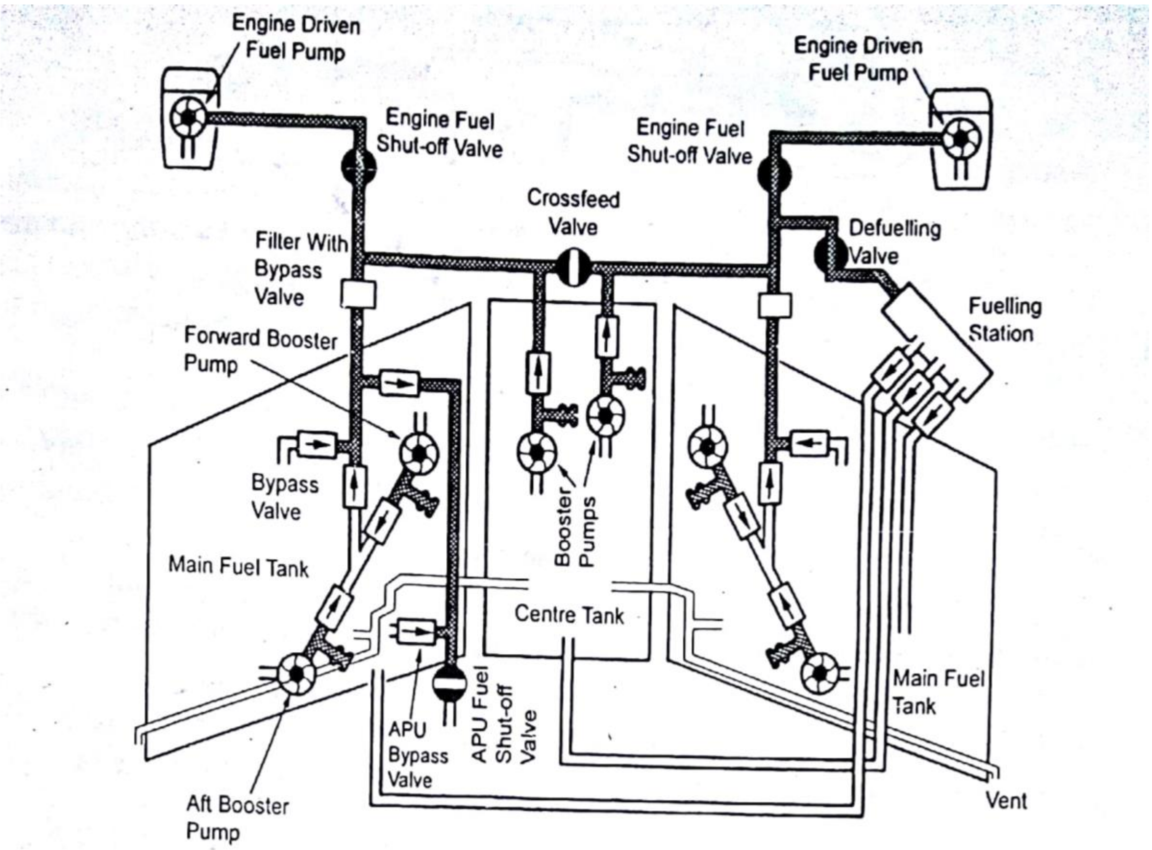


Fig. 32.3

Each main tank has two booster pumps or fuel pumps. The centre tank also has two booster pumps. The centre tank booster pumps supply fuel at a higher pressure than the pumps in the main tanks. Because of this, the fuel in the centre tank is used first before the fuel from the main tanks. The main tanks are located in the wings and the centre tank is located in the fuselage. Cross-feed valve is used on such systems, which enables the engine to draw fuel from the opposite wing tank.

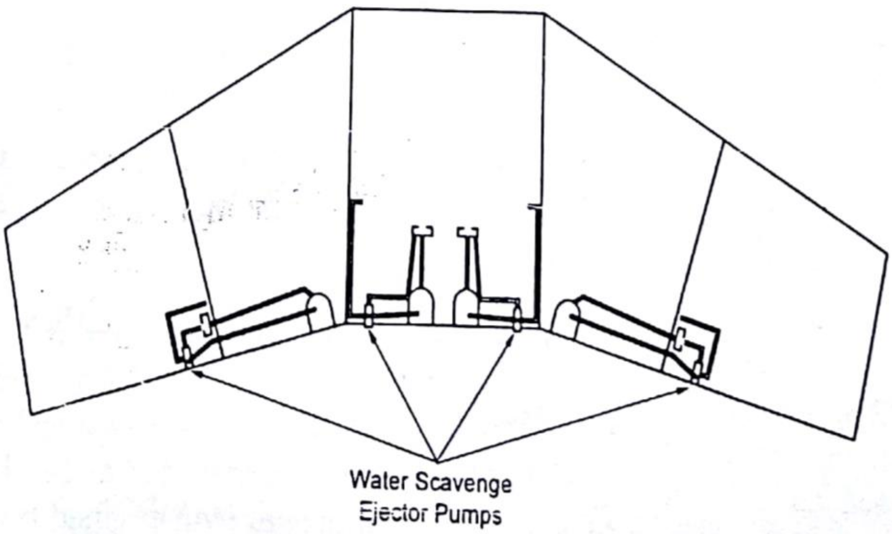


Fig. 32.4

The engine fuel feed system supplies fuel from the fuel tanks to the engines. The fuel control panel controls engine fuel feed. The cross-feed valve permits a single fuel tank to supply fuel to both engines. It lets the fuel flow between the left and right engine fuel feed manifolds. With the connection of the two engine fuel feed manifolds, one fuel tank supplies fuel to both engines. Water scavenge jet pumps are installed in the fuel tanks to remove water from the low points of each tank to prevent corrosion (Fig. 32.4). The APU fuel feed system supplies fuel from any tank to the APU.

The defuel system permits the removal of fuel from each tank. It also permits the transfer of fuel between tanks on the ground. Surge tanks collect fuel overflow only. The fuel overflow in the left wing surge tank drains to the left main tank. The fuel overflow in the right wing surge tank drains to right main tank. If the level of fuel is high enough in the surge tank, the fuel drains out through the vent scoop. The fuel vent system keeps the pressure of the fuel tanks near the ambient pressure. Too large a pressure difference can cause damage to the wing structure. Vent channels and vent tubes equalise the pressure between each tank and the surge tanks when the aircraft is in a climb attitude. The surge tanks are open to the atmosphere through the vent scoop.

The fuel vent float valves equalise the pressure between left main tank, right main tank and the surge tanks when the aircraft is in a cruise or descent mode. The drain float valves in the vent tubes and the vent channels permit fuel in the vent system to drain into the tank when the fuel level is lower than the valve. The pressure relief valve prevents damage to the wing structure when there is too much positive or negative pressure in the fuel tanks. The pressure relief valve is usually closed. When there is too much positive or negative pressure, the pressure relief valve opens. In the open position, the pressure relief valve supplies an additional vent in the surge tank. A typical fuel vent system is shown in Fig. 32.5.

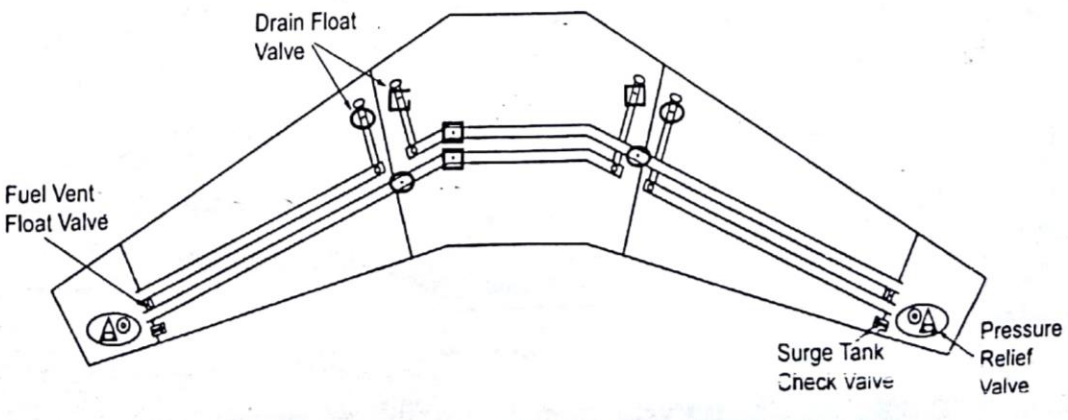


Fig. 32.5

FUEL SYSTEM COMPONENTS

The aircraft fuel system mainly consists of fuel pumps, tanks, valves, fuel flow meters, filters and strainers, quantity indicators, warning components, fuel drains, heaters, etc. Brief description of these components is given in the following paras.

Fuel Pump

Fuel pumps are used to move fuel through the system. The main functions of the fuel pump are - to move the fuel from the tanks to the engines, from one tank to another and from the engine to the tanks.

Fuel Pump Classification

Fuel pumps are classified according to their method of operation such as:

- Vane type
- Centrifugal boost
- Ejector type

Vane Type Pump

Vane type fuel pumps are the most common. They use a rotor which turns the vanes in a cylinder and these vanes act to push the fuel through the system. Vane type pumps can have two to six vanes and they may be variable volume also (Fig. 32.6).

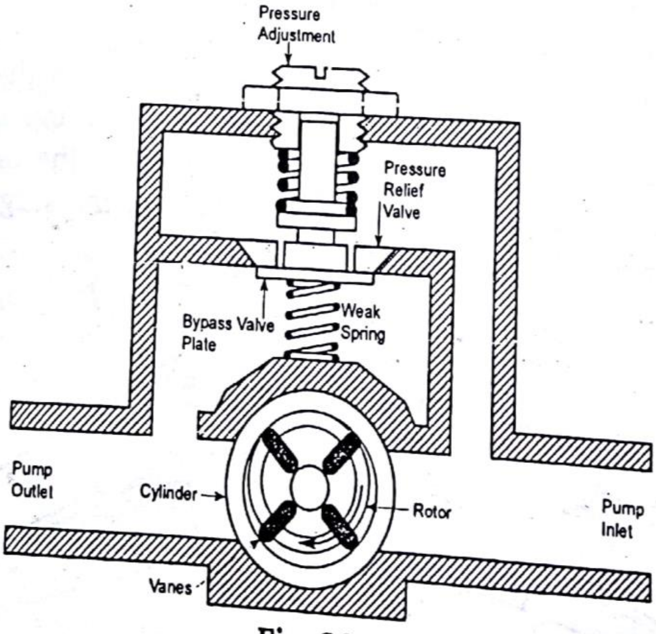


Fig. 32.6

A vane type pump is a constant displacement pump, which moves a specific volume of fuel each time it rotates. Therefore, it must have a relief valve to bypass all the fuel, which is in excess of that required by the engine, back to the pump inlet.

Centrifugal Boost Pump

Centrifugal boost pumps are used to move fuel from one tank to another or from the fuel tank to the engine. They are electrically driven and some may operate at different speeds. Low speed is used to supply fuel to the engines during starting and high speed is used to transfer fuel from one tank to another. These pumps supply fuel under positive pressure at high altitudes where ambient pressure is too low to assure a positive supply. A typical centrifugal boost pump is shown in Fig. 32.7.

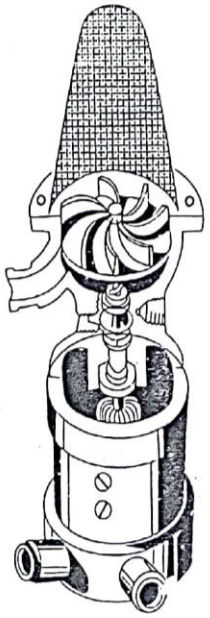


Fig. 32.7

Centrifugal pumps have a small agitator built onto the impeller, which agitates the fuel before it enters the pump impeller. This action releases its vapours before the fuel enters the fuel line. A centrifugal boost pump is a variable displacement pump and its output pressure is determined by the impeller speed. As such, it does not require a relief valve.

Ejector Pump

An ejector pump is normally used to scavenge fuel from remote areas. These pumps have no moving parts. They rely on return fuel from the engine to pump the fuel. Ejector pumps work on the venturi principle (Fig. 32.8).

Fuel Tanks

Fuel systems on different aircraft may use several types of fuel tanks. The location, size and shape of the fuel tanks vary with the type and intended use of the aircraft. The fuel tanks are made of such materials, which will not react chemically with the aviation fuel. The three basic types of fuel tanks used on aircraft are rigid removable, integral and bladder type.

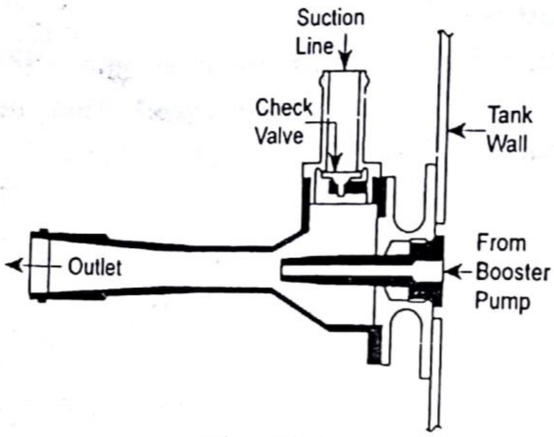


Fig. 32.8

Rigid Removable Fuel Tanks

Rigid removable fuel tanks are often made of aluminium that are welded together. The tanks were made of 3003 or 5052 aluminium alloy due to their light weight and easy weldability characteristics. These tanks are installed in compartments specifically made for this purpose. The tanks may be held in place with straps to avoid their shifting during any manoeuvre. Some sort of padding is provided under the straps to avoid chaffing of the tank against the supporting structure (Fig. 32.9). This type of tank is often found on light aircraft. Due to limitation of space and weight, these tanks have now been replaced by integral or bladder type fuel tanks.

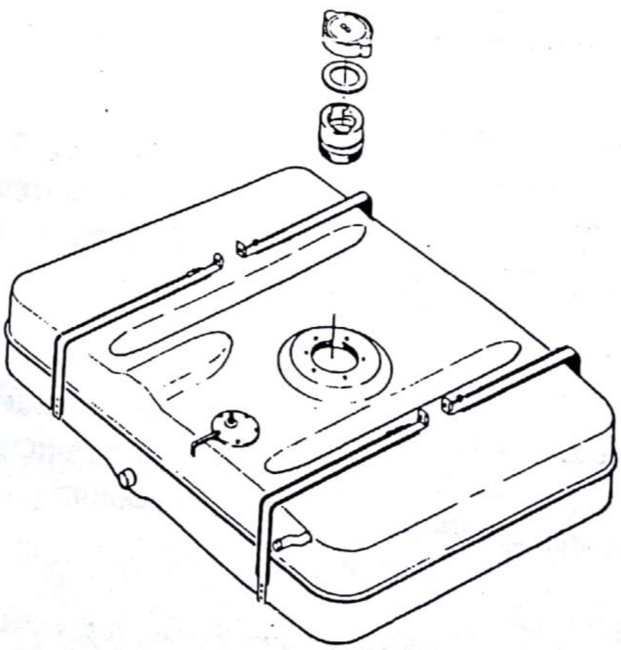


Fig. 32.9

Integral Fuel Tanks

Integral fuel tanks are commonly located in the wings and/or fuselage of an aircraft. These tanks are integrally built into the structure of the aircraft and generally cannot be removed (Fig. 32.10). The seams are sealed, usually with synthetic rubber, to produce an area inside the aircraft structure which will contain the fuel. This type of tank is used due to large weight savings as usage of maximum possible space for carrying the fuel. Integral fuel tanks are generally used on large aircraft.

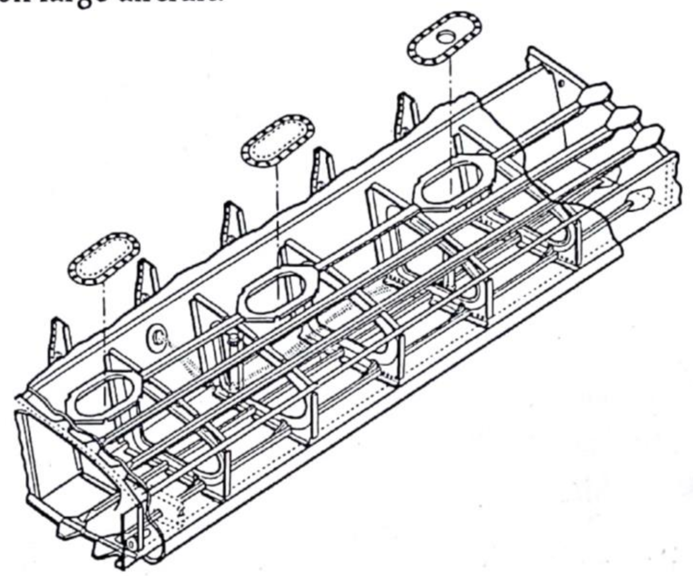


Fig. 32.10

Bladder Type Fuel Tanks

Bladder type fuel tank is basically a reinforced rubberised bag. The bladder is made of thin fabric impregnated with neoprene or some similar material, which is resistant to fuel.

These tanks are installed in compartments which support the weight of the fuel. The bladder is held in place with buttons or snaps on the bottom and sides of the supporting structure. This type of tank is usually found on light aircraft and some turboprop aircraft.

Fuel Valves

Fuel selector valves are used in aircraft fuel systems to shut-off fuel flow, cross-feed and transfer fuel. Selector valves may be operated manually or electrically depending on the installation. Electrically operated valves are normally motor driven.

Hand Operated Valves

Hand operated valves are used on small aircraft. These are either cone type or poppet type.

In a cone type valve, a cone plug made of brass fits into a conical recess in the valve body. The plug is drilled so that it will connect the inlet to any one of the selected outlet. When the handle is turned, a spring loaded pin slips into a detent indicating the alignment of holes in the cone. Detents are used on a fuel valve to provide a positive means of identifying the fully on and fully off position of the valve (Fig. 32.11).

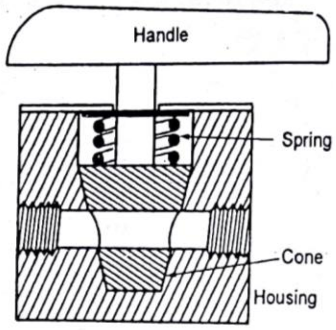


Fig. 32.11

The poppet type valve uses a camshaft to open the poppets and control the fuel flow. The camshaft is operated with a handle. The positive shut-off of fuel is provided by the spring on the valve (Fig. 32.12).

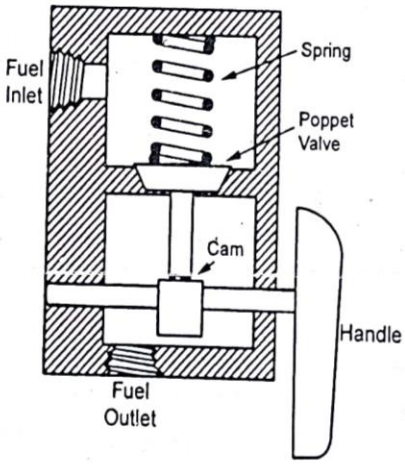


Fig. 32.12

Motor Operated Valves

Electrically operated valves are used in the fuel system of large aircraft. Electrically operated valves are either motor driven or solenoid valves.

Motor operated valve uses a motor driven sliding gate. When the gate is in open position, the fuel is drawn in and vice versa.

In case of a solenoid valve, the electric current which flows through the opening solenoid coil exerts a magnetic pull on the valve stem to open the valve. The valve remains in open position by the action of spring loaded locking plunger of the closing solenoid, which moves into the slot in the valve stem. To close the valve, the current is directed into the closing solenoid coil. The magnetic pull of this coil pulls the locking plunger out of the slot in the valve stem. This results in closing of the valve thereby shutting off the fuel flow A typical solenoid valve is shown in Fig. 32.13.

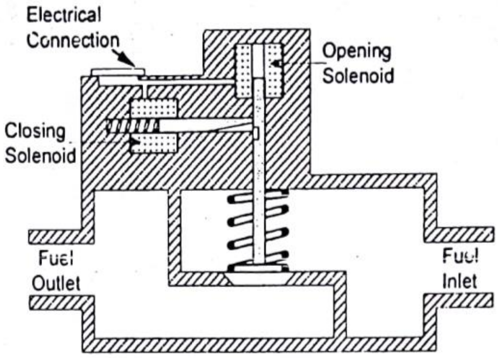


Fig. 32.13

Filters and Strainers

It is imperative that the fuel supplied to the engines is free from any contamination. Due to this requirement, the aircraft fuel system is fitted with strainers and filters.

In general, a micro filter is used, which is made up of a replaceable cellulose filter element. It is capable of removing foreign matter of size varying from 10 to 25 microns. Another type of filter used is wafer screen filter (Fig. 32.14). The filtering element is a stack of wafer type screen disks made of a wire screens.

Fig. 32.14

The function of the strainer is to prevent foreign matter from entering the fuel system and also to trap water, which may be present in the system. Fuel is usually strained at the bottom of the fuel tank and also in the outlet of each fuel tank or at the inlet of the fuel pump. If the strainer is located at the lowest point in the system, it can trap any small amount of water that is present in the system. The strainer located at the tank outlet is a coarse mesh finger screen that traps any large contaminants. A typical fuel strainer is shown in Fig. 32.15.

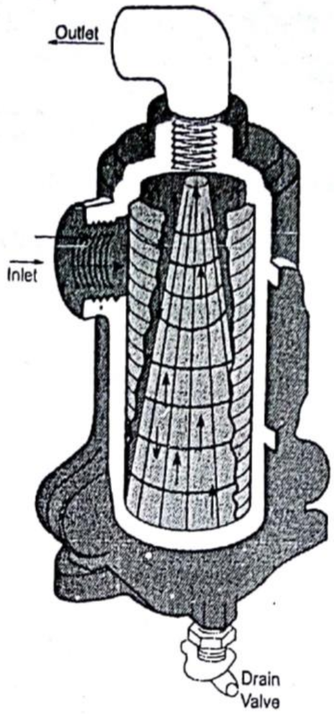


Fig. 32.15

Fuel Quantity Indicators

Various types of fuel quantity indicators used on aircraft are as follows:

- Sight-glass gauge,
- Mechanical,
- Electrical, and
- Electronic.

The type of fuel quantity indicator depends on type of aircraft, number and location of fuel tanks. Light aircraft normally use mechanical type simple float, sight glass gauge or gear assembly fuel quantity indicating system. However, large transport aircraft use electronic type i.e. capacitance fuel quantity indicating systems.

Sight Glass Gauge

The sight glass gauge is the simplest form of fuel quantity indicator. The indicator is a glass tube placed on the same level as the fuel tank. It operates on the principle that a liquid seeks its own level.

Mechanical Type Indicator

The mechanical type indicator is usually located in the fuel tank and is known as direct reading gauge. It has an indicator attached to a float resting on the surface of fuel. As the fuel level changes, the float mechanically operates the indicator, thereby indicating the level of fuel in the tank. A typical mechanical type indicator is shown in Fig. 32.16.

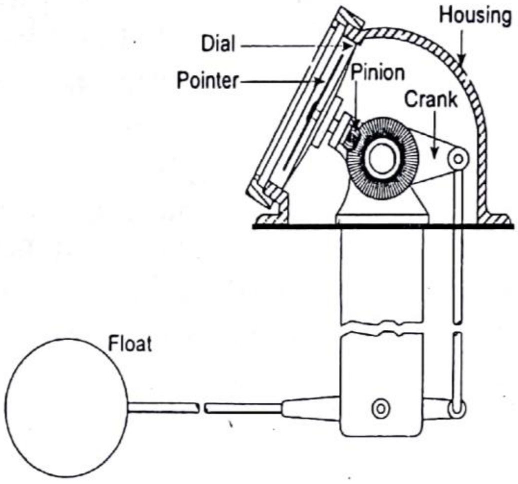


Fig. 32.16

Electrical Type Indicator

The electrical type fuel quantity indicator consists of an indicator in the cockpit and a float type transmitter in the fuel tank. The transmitter consists of a variable resistor mounted outside of the fuel tank (Fig. 32.17). It is operated by an arm connected to a float. As the fuel level changes, the transmitter sends a signal, which shows a changing fuel level in the tank. When the tank is full, the float is near the top of the tank and the resistance is minimum. On the other hand, when the tank is empty, the float is on the bottom and the resistance is maximum.

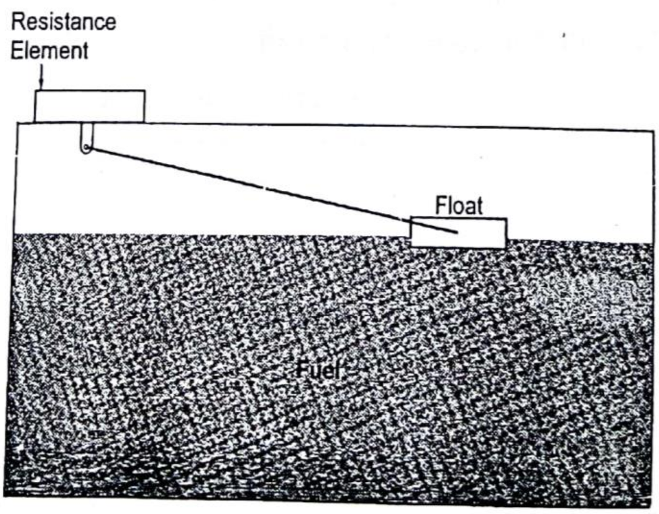


Fig. 32.17

Electronic Type Indicator

Capacitance type electronic fuel quantity indicator has no moving parts inside the fuel tank. The dielectric quality of fuel and air gives the measurement of fuel quantity. The tank transmitter is a simple electric condenser called probe, which is mounted across the tank from top to bottom. The indicator is a servo type instrument driven by a capacitance bridge and a signal amplifier. The dielectric or non-conducting part of the condenser is fuel and air (vapour) above the fuel in the tank. The capacitance of the tank at any point of time depends on the existing proportion of the fuel and vapour inside the tank.

As the quantity of fuel in the tank changes, the portion of the probe immersed in fuel or exposed to air varies. The difference in dielectric values changes the electric capacitance of the probes and the capacitance bridge measures this quantity. The dielectric constant of the fuel also changes with its temperature and density. Due to this, the system is calibrated so that it measures the weight of the fuel rather than its volume.

FUEL SUB-SYSTEMS

Some aircraft fuel sub-systems allow for fuel jettison, heating and cross-feeding.

Fuel Jettison

Fuel jettison system is generally installed on large aircraft to allow the crew to dump or jettison the fuel to lower the gross weight of the aircraft to its allowable landing weight. The fuel jettison system comprises a combination of fuel lines, valves and pumps provided to dump fuel overboard during an in-flight emergency (Fig. 32.18). This reduces the weight of the aircraft so as to enable its emergency landing. A fuel jettison system is required to jettison enough fuel within 10 minutes for general aviation aircraft and within 15 minutes for a transport category aircraft.

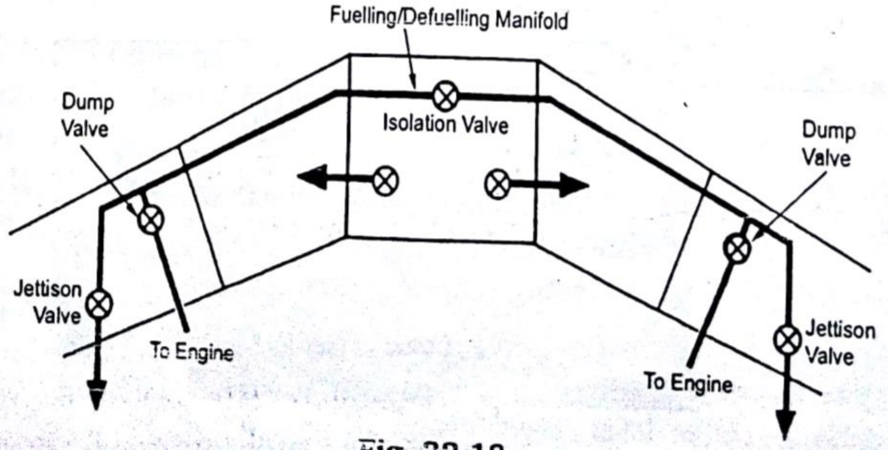


Fig. 32.18